

# HIGHWAY IMPROVEMENTS IN ILLINOIS

BY

I. LEE SEARS

ARMOUR INSTITUTE OF TECHNOLOGY

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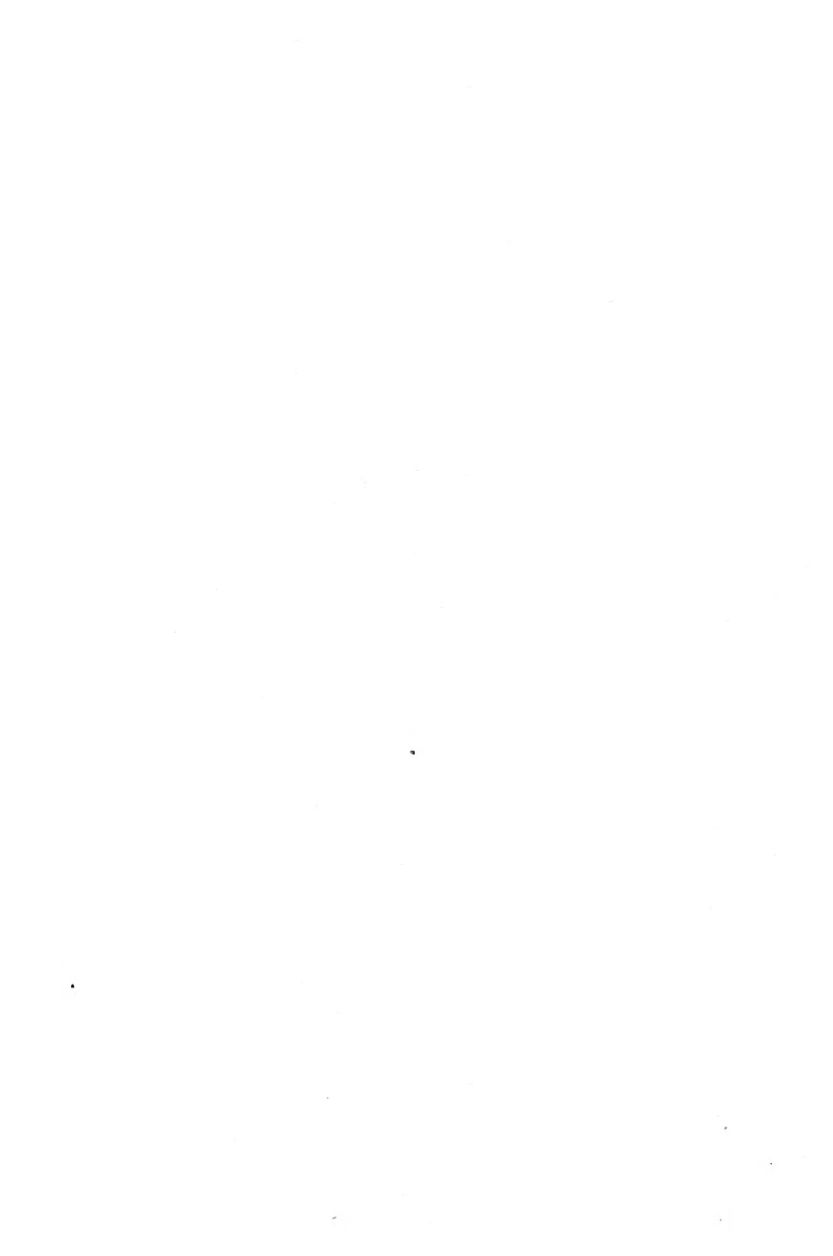
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HIGHWAY IMPROVEMENT IN THE STATE OF ILLINOIS.

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A THESIS PRESENTED BY

*J. Lee Sears*

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TO THE

PRESIDENT AND FACULTY

OF

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FOR THE DEGREE OF

CIVIL ENGINEER.

Approved:

*Walter E. Sears*

Professor of Civil Engineering.

Dean of Engineering Studies.

Dean of Cultural Studies.

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Nineteen-Fifteen.





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## INTRODUCTION.

The State of Illinois to-day presents a vast field for highway improvement. Although it ranks among the leading states in industries and natural resources, it is far below the average when good transportation along highways is taken into consideration. It is the lack of a comprehensive system of roads which prevents the best development of the State.

Up to within the last five years, very little road improvement was carried on. What has been done so far has been of the greatest necessity and only along the central highways of the state. So far, about five hundred permanent bridges and one hundred and fifty miles of improved roads have been constructed. It will require at least fifteen to twenty per cent. of the total road mileage in this state to give sufficient good roadway to produce a fair degree of efficiency.

Traffic conditions have materially changed in the past five years so that the good road and bridge on all traveled highways is becoming a necessity. The time honored hay rack and one horse chaise have yielded their positions as carriers of people and farm products to the motor truck and automobile. The automobile has become a familiar sight in every part of the country, not only for pleasure purposes, but for the rapid transportation of crops. As this must generally be done at a time of the year when the earth road is in poor condition, or even impassable, the permanent or hard road has come to claim serious attention and to stay.





Another factor which has hindered the development of highways up to this time has been the township unit of road administration. This unit is not adapted for the construction of new roads and bridges, or even the maintenance of the quality of road surface required by modern conditions. The pressing need of competent supervision and administration in highway matters has been forcibly brought to notice by the failure of a large concrete bridge near Carmi, Illinois, which was built by private contract and under poor supervision. The thousands of dollars wasted in broken and prematurely worn out equipment has convinced the average person that at least a macadam roadway is necessary on the more travelled thoroughfares.

So strongly had the failure of the system come to popular notice, that the Farmers' Institute adopted resolutions for a change of the system. This change was finally brought about by the passage of the Tice Bill on June 27th, 1913, when the State aid for townships, and the office of County Superintendent of Highways was created. Where formerly a township was unable to maintain even a single main thoroughfare, under State aid probably a mile of new road will be built each year. The executive branch of this work now comes under a trained engineer, and better work can be expected.

The Highway Commission furnishes plans and estimates to any township which desires to improve a road. In the majority of instances the bridges are built by contract, in which case the State furnishes supervision. Few bridges are built by force account. The roads are built mainly on the no-profit



form of contract, where the state furnishes plans, the engineer in charge, the crushed stone, the roller, the roller operator, sprinkling wagon and harrow. The township then pays the freight on the stone and labor.

This thesis aims to present the general method of carrying on this highway improvement, and the results obtained under the present system can best be understood by a description of a typical road and typical bridge. The Leonard bridge represents a fair example of an Illinois highway bridge, and the two sections of the Collinsville Road are typical of the roads in this state. The roads and the bridge were constructed under the supervision of the writer.



## THE LEONARD BRIDGE.

The Leonard Bridge is situated in Cherry Grove Township, on the north and south road from Lanark to Freeport, about seven and one half miles northeast from Lanark, and one-half mile south of the boundary line between Carroll and Stevenson Counties. It is a thirty foot clear span, reinforced concrete, through girder bridge. The load is transmitted from the slab to the girders and through the girders into the abutments. One end is fixed, while the other is free to expand. On slab bridges, the expansion is taken up by the steel in the slabs, a stress of 12000 pounds being allowed for the steel, so that the contraction of the superstructure in cold weather will not produce undue stress in the steel. For spans, thirty feet or over, it is the custom of the Commission to provide expansion by means of rockers. It is more economical than to use enough steel to take up the stress due to temperature changes.

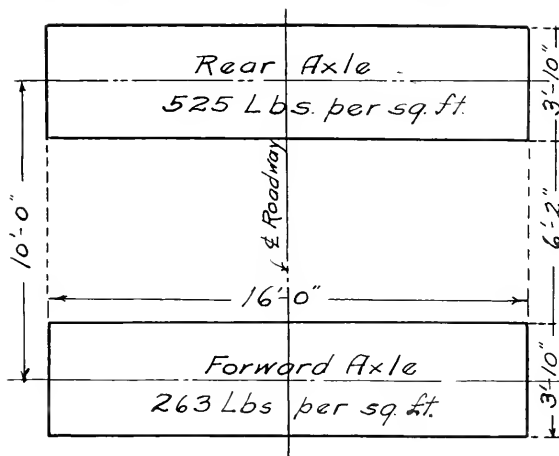
In this bridge the abutments are tied together by the overlapping of the reinforcing rods. Thus the abutment need not be figured for overturning. In some cases in girder bridges, the wing walls of the abutments are entirely separated from the abutment walls, the abutment proper being left free to move at the top with the longitudinal movement of the structure, thus making the wing walls self supporting retaining walls.



# DESIGN OF BRIDGE.

## ROADWAY SLAB.

For secondary roads, the specifications, Article 83, call for a clear width of roadway of sixteen feet. The loading for this type of structure is specified in Articles 92 and 95, and is shown in the following diagram:



The span of the slab is 17 feet from center to center of girders

Live load = 525 lbs. per sq. ft., or 525 lbs. per lineal ft.

$$\text{Dead load of concrete} = \frac{13 + 10}{2} \left( \frac{1}{12} \right) (144) = 138 \text{ " " " "}$$

$$\text{Dead load of earth} = \left( \frac{1}{2} \right) (12) (12) = 60 \text{ " " " "}$$

$$\text{Total} = 723 \text{ " " " "}$$

Using the formula for the bending moment of a simple beam under uniform loading,  $M = \frac{1}{8} w l^2$ , we have,





$$M = \left(\frac{1}{8}\right)(723)(17)^2(12) = 314\ 000 \text{ inch pounds.}$$

$$A_s = \frac{M}{f_s A_j d},$$

where  $f_s$  is the 16 000 pounds per square inch.

j " " .875

d " " 11.43 inches.

A " " steel area required per foot of width of slab.

$$A_s = \frac{314\ 000}{(.875)(16\ 000)(11.43)} = 1.94.$$

For the main reinforcing bars we will use  $\frac{7}{8}$  inch square bars, spaced  $4\frac{3}{4}$  inches on centers.



## GIRDER.

The maximum loading for the girders is obtained by using a uniform live load of 125 pounds per square foot of roadway.

### MOMENT DUE TO DEAD LOAD.

Weight of earth per sq. ft. = 60 lbs.

" " concrete " " " = 138 "

Total = 198 " , say 200 lbs. per sq. ft.

(8)(200) = 1600 lbs. per lin. ft. of girder from roadway.

$(\frac{4.5}{6})(1)(144) = 696$  " " " " " " from girder.

Total = 2296 " " " " " " . Use 2300 lbs.

Dead load moment =  $(\frac{2300}{8})(30)(30)(12) = 3\ 105\ 000$  inch lbs.

### LIVE LOAD MOMENT.

(125)(8) = 1000 lbs. per foot live load to each girder.

Live load moment =  $(\frac{1}{8})(1000)(30)(30)(12) = 1\ 350\ 000$  in. lbs.

Dead load moment = 3 105 000 inch pounds.

Live load moment = 1 350 000 " "

Total = 4 455 000 " "

$A_s = \frac{M}{f_s j d} = \frac{4\ 455\ 000}{(16\ 000)(.87)(48)} = 6.63$  square inches.

This requires four  $1\frac{1}{8}$  inch square bars and two 1 inch square bars.

### DIAGONAL SHEAR.

The diagonal shear in the girders is taken by means of the vertical stirrups which are the  $\frac{1}{2}$  inch square bars "s" shown in the plan of superstructure.

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## ABUTMENTS.

The main wall of the abutment is figured as a vertical slab supported at the top by the superstructure and at the bottom by the footing. Since the abutment rods are anchored in the wing walls, we are justified in assuming that the overturning will be taken up by the wing walls.

An equivalent fluid pressure of fifteen pounds per square foot is taken as the basis of calculation.

For the lowest section of slab of 45 inches, we use 13.5 feet as the height of the earth pressing against the slab. The term "h" will then be 13.5 feet, in the formula,

$$M = P h \left( \frac{l}{8} \right)$$

where M is the bending moment on the slab at that section due to earth pressure;

P is the equivalent fluid pressure back of the wall;

h is the height of fill above the bottom of the section considered; and

l is the length of slab between supports.

Here "l" is 18 feet.

$$\text{Then } M = (15)(13.5) \frac{(18)(18)(12)}{8} = 98200 \text{ inch pounds.}$$

But  $M = f_s A j d$ , where M is the bending moment in the slab;

$f_s$  is the allowable stress in the steel,  
= 16000 lbs.

A is the area of steel required per foot

j is .875; and

D is the effective depth of slab from the top of slab to the center of gravity of the tension steel.

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Then  $M = 98200 = (16000)(.875)(A)(10)$ , or  $A = .703$  sq. inches.

This requires  $\frac{3}{4}$  inch square rods spaced at 9 inch centers, which gives a steel area of .75 square inches.

For the 45 inch width of slab, use five  $\frac{3}{4}$  inch square bars spaced 9 inches on centers.

For the next lowest tier of 36 inches, use a height of earth on slab of 8.0 feet. By using the same method of calculation, we have

$$M = (15)(8) \frac{(18)(18)(12)}{8} = 58350 \text{ inch pounds.}$$

$$M = 58350 = (16000)(.875)(A)(10), \text{ or } A = .417 \text{ sq. in.}$$

This requires  $\frac{9}{16}$  inch square bars spaced 9 inches on centers, but we shall use  $\frac{5}{8}$  inch square bars on 9 inch centers.

For the remaining section, use seven  $\frac{1}{2}$  inch square bars, 9 inches on centers, which gives a steel area of .33 square inches per foot.

For vertical reinforcement, use  $\frac{1}{2}$  inch square bars, 12 inches on centers.





## WING WALLS.

The wing walls are figured as self sustaining retaining walls. The vertical steel takes care of the overturning.

In these calculations the equivalent fluid pressure of 15 pounds per square inch will be used.

In the formula,  $M = (\frac{P h^2}{2}) (\frac{h}{2})$ ,  $h$  will be taken as 13 feet.

$M$  is the overturning moment.

$P$  is the equivalent fluid pressure.

$h$  is the height of earth back of the wing walls causing overturning moment.

$M$ , the overturning moment, then becomes,

$$M = (\frac{(13)(13)}{2})(15)(\frac{13}{2}) = 65\ 910.$$

The resisting moment is the resisting moment of the steel through a lever arm of ten inches, or

$$M_R = (A_s)(10)(j)(16\ 000), \text{ therefore,}$$

$$M_R = 140\ 000 A_s.$$

$$A_s = \frac{65\ 910}{140\ 000} = .471.$$

$\frac{5}{8}$ " square rods spaced ten inches on centers give an area of .47, which satisfies our conditions. For temperature steel use  $\frac{1}{2}$  inch square bars, 12 inches on centers.

For vertical steel, use  $\frac{5}{8}$  inch bars spaced 10 inches on centers.

For horizontal steel, use  $\frac{1}{2}$  inch square bars spaced 12 inches on centers.

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### FOOTINGS UNDER WING WALLS.

The overturning moment of the wall is 65 910 inch pounds. This is resisted by the weight of the concrete and the weight of earth on the footing back of the wall, acting through their lever arms about the toe of the footing.

Weight of concrete in stem	=	(1)(11)(150) times	
		lever arm of 15 in.	= 24 750 <sup>in</sup> / <sub>lbs</sub>
" " base	=	(11)(5)(150) times	
		lever arm of 30 in.	= 33 750 " "
" " earth on footing	=	(3 $\frac{1}{2}$ )(11)(100) times	
		lever arm of 41 in.	= 146 500 " "
Total			<hr/> 205 000 " "

Factor of safety against overturning =  $\frac{\text{Resisting moment}}{\text{Overturning moment.}}$

$$\text{Factor of safety} = \frac{205\ 000}{65\ 910} = 3.12.$$

The specifications call for a width of footing of 0.4 of the height.  $(0.4)(12.5) = 5' 0''$  which is the width assumed.

$$= \frac{1}{2} \left( \frac{1}{2} + \frac{1}{2} \right) = \frac{1}{2}$$

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$$= \frac{1}{2} \left( \frac{1}{2} + \frac{1}{2} \right) = \frac{1}{2}$$

## BENDING OF STEEL.

GIRDER. The six main bars in each girder were hooked at each end to provide the necessary bond between the steel and the concrete. The lower two bars were carried straight to the ends of the girders while the four upper bars were bent as shown, to aid the vertical stirrups in carrying diagonal shear. The stirrup bars were bent in the form of a "U". The vertical reinforcement near the center of the girder was bent in the form of the "U", as it was found that the "U" could be more easily handled in the forms.

SLAB. The main slab bars consisted of bent bars, "a", "a<sub>1</sub>", "a<sub>2</sub>", "a<sub>3</sub>". The bars "a" and "a<sub>1</sub>" were bent so as to remain a part of the slab. The bar "a<sub>3</sub>" contained a 45 degree bend and a hook at each end to develop bond stress. The bar "a<sub>2</sub>" contained a 45 degree bend and a long arm extending into the girder, very nearly to the top. These bars not only take care of diagonal shear and bond stress, but also tie the slab to the girder. The diagonal shear in the slab is taken care of by means of the continuous 4 loop bars "r". One bar "r" is placed on each end of alternate floor bars.



## LEONARD BRIDGE.

### DISCUSSION.

The soil at the south end at this bridge was a stiff yellow clay to an elevation of about 2 feet above the bed of the stream. From this elevation down to 2 feet below, a loose gravel and clay was found, and below this to 4 feet below the stream bed, was a stiff blue clay. On the north end, the stiff blue clay formation was overlaid by a strata of very soft clay about one foot thick. Considerable water was encountered at this bridge site, as the bridge is located in the ravine between a series of high hills. During rain storms it was impossible to work, as the flumes were carried away and the water rose to a height of from four to six feet above the stream bed.

An unusually large amount of cement was used in this bridge, as the aggregate furnished contained too large an amount of sand. As class "A" concrete, 1:2½:4 was specified, the relation of sand to stone volume must be 0.60. If it is more than that ratio, the strength of concrete is greater, provided the ratio of cement to sand is always constant. In this case the contractor preferred to add the extra cement rather than lose time by waiting for gravel to be added to the aggregate he had on hand. It was found that the percentage of sand in the total original gravel was 88.

For class "A" concrete the specifications require that the number of sacks of cement to be used to each cubic yard of pit run gravel =  $\frac{(27)(.88)}{(.95)(2.5)} = (11.37)(.88) = 10.0$ .





10 sacks in place of  $6\frac{1}{2}$  sacks would be required if the ratio of sand to stone were .60.

This shows that the bridges rebuilt by the State Highway Commission cannot be built out of sand without using an extra lot of cement. Most pit run gravel in the East contains an excess of sand, so that additional large aggregate is required.

#### MIXING AND POURING THE CONCRETE.

All the concrete was mixed in a half yard batch mixer.

On account of the amount of bent steel in the structure, the mixture was made sloppy so that it would flow easily around the bars and form a good facing when spaded. With this amount of water used, all the cement was well hydrated, thus doing away with the more glaring fault in concrete construction, that of under-hydration.

For the footings, the mix was made a little less sloppy, as this concrete had to be placed under two to four feet of water. For the footings, the concrete was chuted down wooden chutes, so that the mass would not segregate by a twenty foot drop.

In pouring the slab, the concrete was placed starting at the middle and poured both ways until the ends were reached.

This was done to prevent cracks between the floor and the abutments. When the concrete is started at one abutment and continued toward the other, the concrete directly at the abutment assumes its initial set before the floor is one-quarter poured. By the time the middle is reached, the end on the abutment tends to break away, leaving a crack in the concrete before it has fully set.



## EXCAVATION.

Above the water line the banks were stepped down by means of steps 3 feet wide and 2 feet high. When the water line was reached, it became necessary to brace between the sides of the bank. Walings of 3" x 12" were placed against the face of the excavation and scabs of 3" x 12" material were placed against them. Between these scabs, struts of 8" x 8" size were driven to a tight fit. As most of this sheathing and bracing was old lumber from the old bridge floor, it was not considered advisable to salvage any of this bracing below the water line, so that it was left under the back filling.

## FORMS.

The forms for the wing walls and abutments were placed directly on the footings. Two 2" x 4" pieces were laid on the top of the footing to serve as a base for the studs for the walls. The walls were made of 1" x 10" sheathing well nailed, in order that the cracks between boards might be a minimum. The sheathing was nailed to 3" x 6" studs, spaced at 21 inch intervals. The studs in turn were set on the 4" x 4" sills which were laid directly on top of the footing. On both sides, the forms were completed before any concrete was poured, so that the entire abutment would be homogeneous.

While the forms for the walls were being built, three 8" x 8" posts were set in place to serve later on as supports for the falsework and girders. The posts were set directly on top of the footing. One was placed at each end and one in the middle of the abutment. This allowed three lines of stringers to support the false work.



# VOLUME OF CONCRETE IN BRIDGE.

## SUBSTRUCTURE.

Wing Walls	$2 \left\{ (1) \left( \frac{11 + 15.25}{2} \right) (13\frac{5}{6}) \right\}$	=	355.5	cubic feet
Abutment Wall	$(1)(12\frac{1}{4})(18)$	=	220.5	" "
Abutment Footings	$(1\frac{1}{2})(3)(18)$	=	81.0	" "
Wing Wall Footings	$2 \left\{ (1\frac{1}{2})(5)(14) \right\}$	=	<u>210.0</u>	" "
Total			867.0	" "
Less			<u>27.25</u>	" "
Net			839.75	" "

$$\frac{839.75}{27} = 31.1 \text{ cubic yards.}$$

For the 2 abutments, this will require 62.2 cubic yards.

## SUPERSTRUCTURE.

Girder	$2 \left\{ (1) (4\frac{5}{6}) (33) \right\}$	=	319	cubic feet
Slab	$\frac{(15 + 10)}{(2)(12)} (16)(33)$	=	506	" "
Wheel Guards	$2(\frac{1}{2})(\frac{1}{2})(33)$	=	<u>16.50</u>	" "
Total			841.50	" "

$$\frac{841.50}{27} = 31.1 \text{ cubic yards.}$$

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## THE TROY - COLLINSVILLE ROAD.

### JARVIS TOWNSHIP.

The Troy - Collinsville Road is situated in Jarvis Township, Madison County, Illinois, about twenty miles east of East St. Louis. It begins at the westerly limits of the town of Troy and extends westward for a distance of one mile. It is a part of what is known as the Old National Road, which at the present time is being improved with the view of its becoming the great transcontinental highway from the Atlantic to the Pacific Ocean. It is in the direct line of travel from the eastern part of the state to St. Louis. The traffic on this highway is for the most part, automobile traffic, which requires a good even road.

The soil on this road is mostly a light colored clay which dries out in the summer and grinds to a very fine dust, so that vehicles traversing this highway become completely covered with dust. This not only makes travel unpleasant, but it creates a dust nuisance to the homes located along this road. In the winter time this soil forms a quagmire and becomes impossible for travel.

The traveled roadway of this highway was very small, as the sides of the road were taken up by great banks of earth ten to twelve feet wide. These banks made drainage difficult as the loosened material filled up the drainage ditches. To meet the necessary conditions, the stone roadway was made





twelve feet wide and was designed to be constructed as a water-bound macadam road in two courses.

Each course is four inches thick after rolling, so that the total thickness of stone is eight inches. In the stone section there is a crown of four inches, while the shoulder commencing at the edge of the stone, drops away on a slope of 1 : 10, to provide good drainage. The earth shoulder was made ten feet wide on each side. From the edge of the shoulder, the earth is trimmed off on a slope of 2 to 1 on the fills and on cuts on a  $1\frac{1}{2}$  to 1 slope. These slopes have been found in practice to be the most economical to maintain.

The gutter formed by the shoulder and the side sloper on cuts has been found to be ample to carry away the water from the road. However, during extremely heavy rains, the water may overflow the entire road, but this will not injure the road, as it is drained away in a very short time.

The shape of the subgrade is crowned parallel to the top surface of the stone. This is done for two reasons. The prime reason is drainage during construction. The subgrade may be open two or three days before the stone is laid. After the stone is laid, three or four days may elapse before it can be rolled. During that time, heavy rainstorms may come and fill the trench. The whole subgrade and stone must then dry out before it can be rolled, unless the water is at once drained away so that the subgrade is not softened. The crowned subgrade draws the water to the sides, whence it can be drained away by lateral drains. The second reason is that stone can be



rolled more easily to shape when the base and the top are parallel. This has been found by experience.

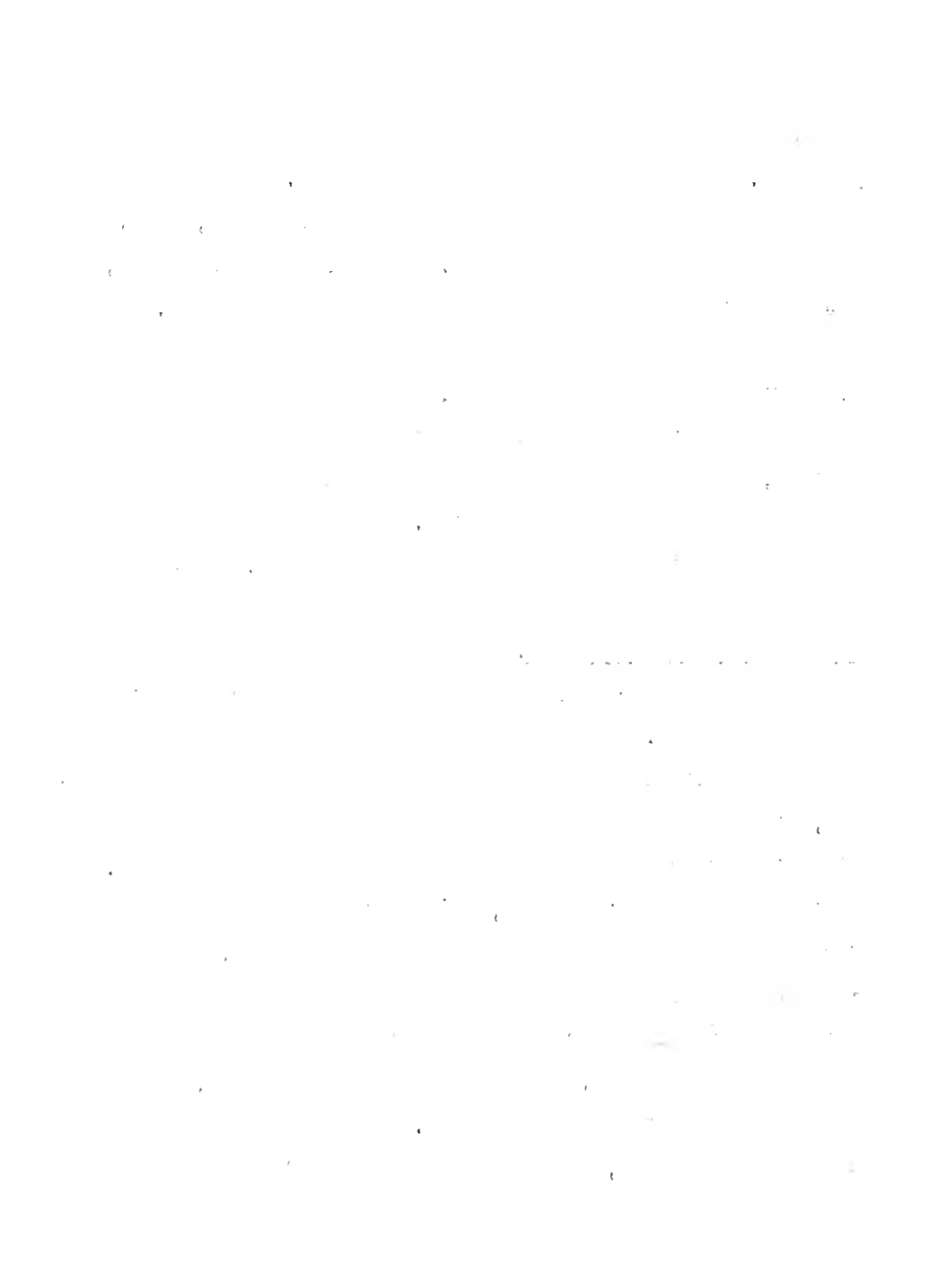
Work was started on this project on May 1, 1912. The earthwork was begun at Station 3. A heavy railroad plough, drawn by eight horses, was used to break up the ground. The loosened material was then hauled by slips to Stations 5 and 6, to fill to the required grade. When the earth had been excavated to within three or four inches of the grades prescribed, the grader drawn by an engine, was used to bring the subgrade to the accurate elevation. A slight amount of hand labor was required in trimming up the shoulders.

#### GRADING SUBGRADE BY ENGINE.

The subgrade on the light grades was prepared in the following manner.

A light cut was taken about four feet from the shoulder, with the blade of the grader set about  $20^{\circ}$  with the direction of travel and the cut taken with the front point.

With each successive round, the cutting was carried a foot farther towards the shoulder and the cut deepened. When the cutting approached the line of shoulder, the blade was set a trifle outside of the front wheel while the wheel was kept close to the shoulder. During all these operations, the loose earth had been piled in the center. When the subgrade had been cut to the shoulder, the blade was set at  $45^{\circ}$  to throw the dirt back onto the shoulders where it was leveled off to proper shape



The grader was drawn by a 16 horse power Case Tractor, and proved far more efficient than the horse drawn grader.

### PLACING OF STONE.

For a twelve foot width of roadway, eight inches in thickness, eighteen cubic yards of stone are required in each course for 100 lineal feet of road. As this stone was hauled by farmers who received 40 cents per cubic yard for the short haul and 50 cents for the long haul, and every wagon had a different capacity, it was necessary to adopt a scheme of determining the number of loads to be dumped at each section.

All the wagons were measured and their capacities marked on the side of the wagon. To each hundred feet then, the necessary number of loads was dumped to make 18 cubic feet per 100 feet of road. As soon as a stretch of about 400 to 500 feet of stone was dumped, the grader was put to spreading the stone. The first four trips were made with the blade of the grader set at right angles to the road and the tops of the loads dragged out lengthwise of the road. The blade was set at angle to the roadway, and at an angle to conform to the crown of the roadway. When the roughest work had been done with the machine, men with hand rakes finished the stone to very nearly the true cross section.



### HARROWING.

At this juncture, a harrow was put on the stone and five or six trips were made each way with the harrow. This was to bring the larger stone to the top, and to shake down the dust, dirt and smaller stone. Generally when the stone is dirty, the whole section of the road will creep before the roller, leaving a ridge at each stop. This is avoided by thorough harrowing.

### ROLLING.

Considerable difficulty was experienced in obtaining a roller to do this work, so that it was necessary to lay two courses of stone, making a total thickness of ten inches of large stone to be either compacted by traffic, or wait until the road roller arrived. As this condition was becoming more and more common on account of the number of townships desiring roads, and the scarcity of rollers, it was decided that the stone was to be placed and the road then thrown open to traffic.

The traffic, however, refused to take the rough stone roadway, so that in consequence the shoulders became badly rutted and the road left unrolled. The method of spreading chat on the top of the rough stone was resorted to in hopes that the traffic would then utilize the stone way. The traffic immediately began to use the stone road, and as the stone became rolled down and ruts worn, men were put to work to fill up the ruts and spread more screenings. When the roller finally arrived,





the stone had been more than half rolled, so that very little rolling remained to be done. After rolling, more screenings were spread and the whole screening top was waterbound.

#### BINDING.

The rolling and sprinkling continued until there was a solid layer of about  $\frac{1}{4}$  inch to  $\frac{1}{2}$  inch of ground chat on the whole surface and the water was flushing to the top. When soft spots appeared where the water had softened the subgrade, the part was left to dry out, after which it was rolled.

#### GENERAL METHOD OF ROLLING STONE.

Lower Course. The roller commences to roll at the shoulder. It should run at a speed of about one hundred feet per minute. With each successive trip the roller moves toward the crown, about half a wheel width. When the center is reached, the roller should work the other side toward the center in the same mound. The rolling should be repeated alternately until the lower course is thoroughly compacted, but not rolled so long that the key will be rolled out of it.

Upper Course. For the upper course, the roller commences to roll the shoulder five feet out from the edge of stone. This is done to compact the earth shoulder so that the stone will have bearing and not spread. The rolling continues in the manner described for rolling the lower course. It is essential that the key is not rolled out of the upper course by too much rolling, as the screenings will not hold on a surface which is not well keyed.

#### GENERAL METHOD OF APPLYING SCREENINGS.

The twelve foot road will require about five cubic yards of screenings per hundred lineal feet. This must be



distributed in small piles along the shoulder, clear of the rolling. Immediately after rolling, the screenings must be whipped in with a square pointed shovel. The whole surface must be thoroughly covered. The top is then brushed over with a stiff broom, to work the screenings into the crevices. After no more screenings can be worked in, about  $\frac{1}{4}$  inch thickness is evenly spread on top. This will then require a wetting to wash in the finer particles. The operation is generally done the last thing in the evening. In the morning, more screenings are spread to cover the bare spots. The portion of the road is then ready to be puddled or water bound.

#### CORDUROY ROAD.

Near the Smith's Lane, a stretch of corduroy road of about 50 feet was encountered. As the plans called for very little excavation at that point, it was considered advisable to entirely remove the logs and fill the hole with cinders. It was expected that this spot might develop a spring at some later time, and the cinder fill would act as a blind drain.

#### WET SUBGRADE.

From Station 9 to Station 11, a wet spot was encountered. The whole area was tiled with 4 inch porous tile and then filled with cinders and left to pack. This subgrade held very well when the roller was put on.

On some of the sections of this road, the subgrade became softened by the rains, and though the lateral drains



were working, the soil seemed to hold water. When the roller was first put on the stone, the whole stone mass began to key.

After three or four trips, the stone began to creep in waves ahead of the roller, and the wheel began to wear a depression as it went along. These spots were left until they dried out.

The stone was then re-raked, the hollows filled in with more stone, after which these places could be keyed and waterbound.

### GUMBO.

From Station 20 to Station 25, a vein of gumbo crossed the roadway. This portion of the road was left to the end, in hopes that it would soon dry out. While the dry season lasted, the top two inches became as hard as rock, but the very first rain softened it so that a heavily loaded wagon sank into it five or six inches. A portion of the road of about 100 feet was used for experimenting. The stone was placed and the traffic turned upon it. The stone began to disappear, and the gumbo began to work to the top. Load after load of stone was placed here but it kept on disappearing as fast as it was placed. On another stretch of 50 feet, the subgrade was covered with a layer of three inches of screenings or chats. When the traffic was turned in upon this, the gumbo and the chat mixed into a formation very similar to hardpan in its action. The traffic rode over this portion as if over a concrete walk.

It was then decided that the only way to put a water-bound macadam road on gumbo was to build the foundation of chats or screenings, and then place the larger stone on top of this and roll it in the usual manner. On account of the large



amount of chats used in the construction of this road, it was dubbed the "Chat Road".





THIRD SECTION TROY - COLLINSVILLE ROAD  
COLLINSVILLE TOWNSHIP.

The third section of the Troy - Collinsville Road was constructed late in the season of 1912. It is a continuation of the work done previously, and runs for a distance of 4900 feet eastward to the Troy station on the Interurban Railroad.

The cross-section is shown on the plan. Special cross-section was necessary on account of the tracks of the Edwardsville and Collinsville Interurban Railroad Company being located on the east side of the road. The macadam is 8 inches thick and 14 feet wide, with a shoulder of from 6 to 10 feet wide, depending on the location. The ground at this point is very hilly. Between Stations 4 and 6, the road is located over a ravine, the bottom of which is about 30 feet below the surface of roadway.

The previous section was built close to the railroad track, but it was found that the side near the tracks was worn very little, while the outer half was used by traffic going both ways. For this section it was decided to place the edge of the stone five feet away from the rail so that the traffic would spread over the whole stoneway.

In this section the road is virtually in the valley between two ranges of hills. Consequently the rain falling on these hills on either side, rapidly finds its way to the gutters along the roadside. During heavy floods, the road is covered with from 6 to 8 inches of water along the level portion from



Station 19 to Station 24. To relieve this condition, it was decided to provide greater drainage section than the ordinary waterway. The slope of the shoulder was made 5 inches in 6 feet. In the next 4 feet, the ground dropped one foot to provide a deep triangular trough about a foot deep and 6 or 7 feet wide. A large amount of earthwork was necessitated to bring the road to grade. The finished grade approximated very closely the profile of the railroad. The soil is mostly a light colored clay which is rather difficult to work. From Station 0 to Station 7, the road had been filled in with slag from the lead smelter, and to prepare the subgrade, this had to be removed with pick and shovel and transported to Station 27 for fill.

From Station 29 to Station 35, gumbo was encountered. This proved to be a serious difficulty in rolling, and the chat, method described in a previous portion of this treatise, was used in making a foundation.

Every foot of subgrade for this stretch was rolled to unyielding. The bottom course consisted of one inch stone which was very dirty, but after careful harrowing formed an excellent foundation. The top course was built of  $2\frac{1}{2}$  inch stone, so well keyed that a horse walking upon the newly rolled surface disturbed it but very little.

After each rolling, chat was spread, and a light rolling given without watering. The binding was deferred until a stretch of about a thousand feet could be bound at one time.

Everything was in readiness to give the road from Station 0 to Station 8 a final binding when a gentle rain came up. This pre-



ised to be a very excellent method of sprinkling for binding, so the roller was brought on the road and run at a speed of about 150 feet per minute. The rain lasted one hour, just long enough to puddle the road. This same puddling with carrying water from the pond would have taken about four hours, besides requiring four horses and three men. There was just enough rain to wash the wheels to prevent the chat from being picked up, and not enough to soften the subgrade. This stretch later showed up the best and was as even and compact as a concrete roadway.

An 18 inch culvert at Station 28 + 60 was found to be inadequate. Thirty-six inch pipe was laid and covered in a concrete coat of 12 inches, to prevent washing out.

#### CULVERT.

At Station 29 the culvert consisted of a 18 inch pipe laid across the roadway. As this section of the road was often-times under 6 to 8 feet of water during heavy flood, the only remedy was to provide greater waterway. The old culvert was torn out and a 30 inch vitrified tile culvert was built. The head walls were carried down four feet below the level of the invert to prevent underseour in this formation. The top of the sidewalls was carried to a height of four feet above the road.



## ROAD SURVEYS.

As the time that can be allotted to the survey of any one road is necessarily short, the minimum of work with the maximum information must be carried out. The transit line is run approximately midway between fence lines, for the Highway Commission does not enter deeply into disputes of overlapping fences. The basis is generally a permanent monument to which reference can be made at all times.

Station "O" is accurately tied in with the monument.

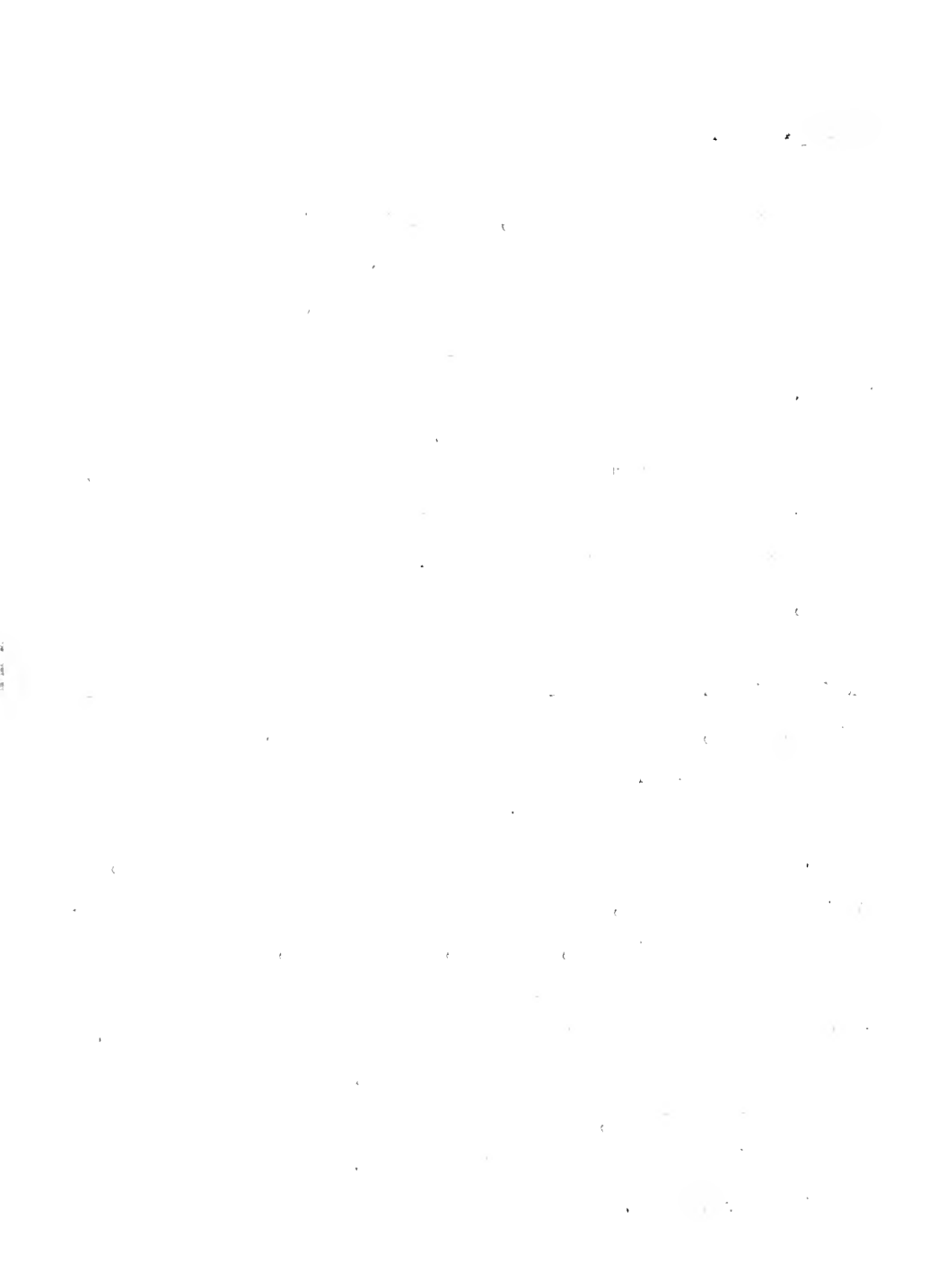
The first leg of the transit line is very accurately located so that it can be readily picked up. Where a turn in the road occurs, the transit is set up and the azimuth of the new line is recorded together with the magnetic bearing of the foresight and backsight. Each one of the points where the line breaks, is referenced in, so that when construction begins, these points are easily located.

Immediately following the transit is the levelling party. Cross-sections of the road are taken every 100 feet, at every break in grade, and at fence lines of intersecting roads.

Every driveway, gateway, all ditches, fences and walls are recorded in the survey, and elevations taken of any of these features which may be affected by changing the present grade.

The travelled roadway is always located.

All bridges, culverts and drains are accurately located and their correct elevations taken. High water marks are especially valuable.



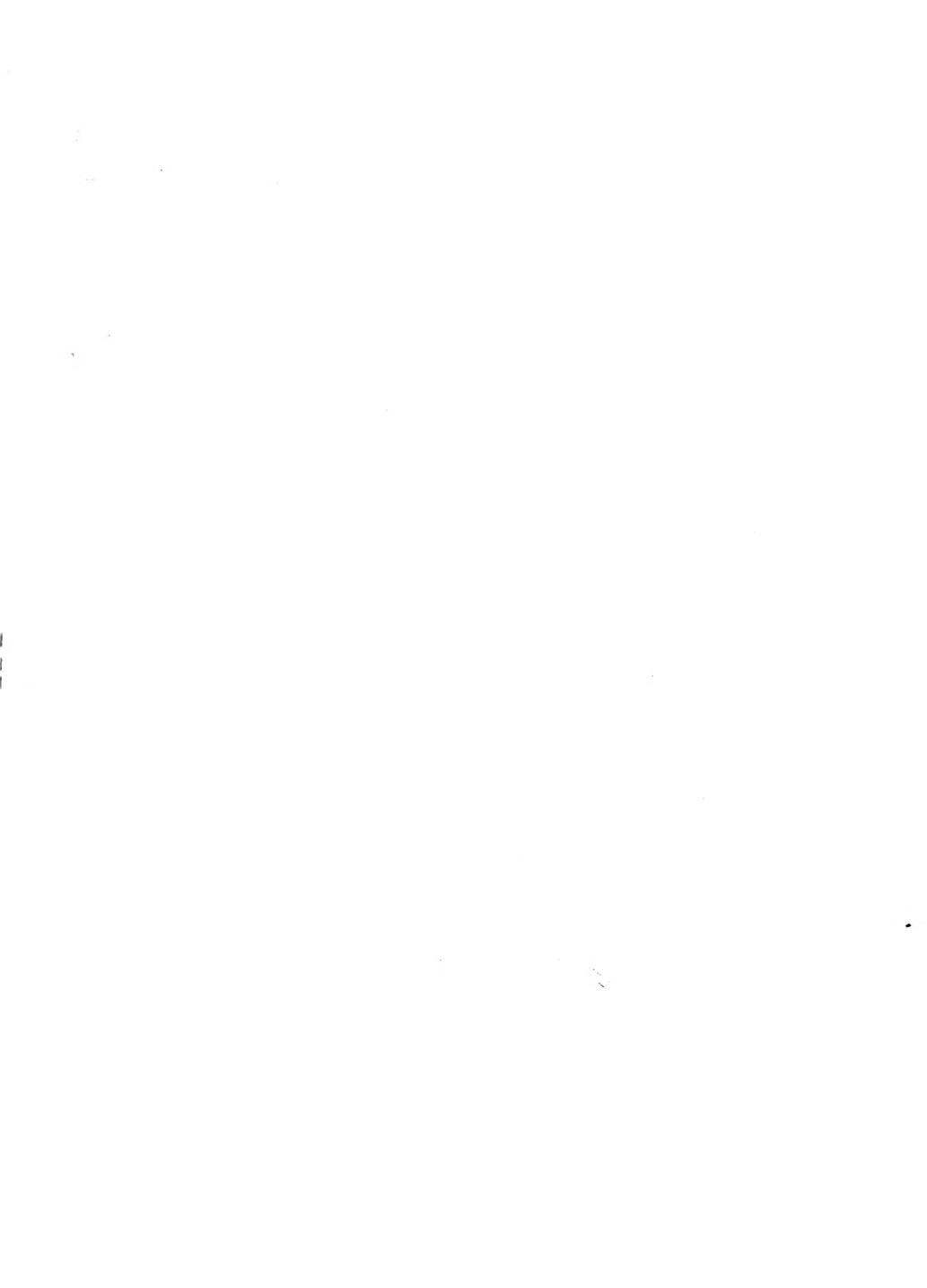


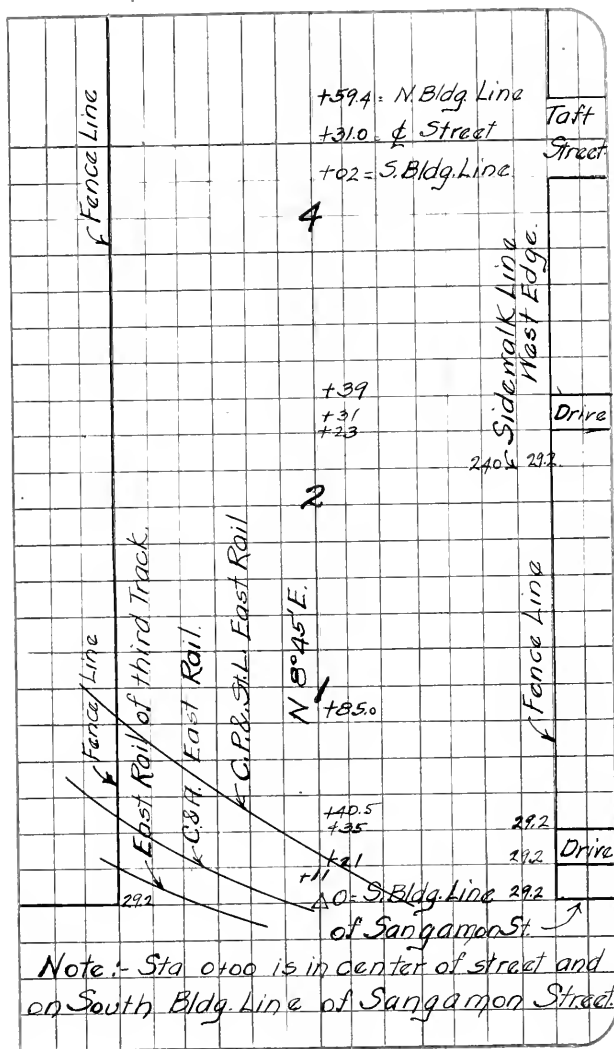
Permanent benches are established wherever convenient along the roadway. Their number and elevations are always recorded on the bench itself to facilitate the construction later on. A sample page of each side of the note book, is shown.

The notes are a part of the survey made by the writer for the sixteen foot concrete roadway on the Springfield - Peoria Road.



Sta	+	H.I.	-	Elev					
B.M.#1 on Intersection of N. Bldg Line of Sangamon St. and West Edge of Concrete Walk El. 155.40									
4+59.4		49 5.8	44 29 6.8 5.7	25 5.7	8 3 0 6.1 7.0 5.4	154.78 153.98 154.88 155.08 154.88 153.58 155.38			
4		55 44 5.0 5.7	29 5.1	23 4.8	8 4.8	6 0 6.3 4.7	155.78 155.08 155.68 155.98 155.98 154.48 156.08		
3		50 5.1	44 5.3	29 5.0	22 4.8	5 5.7	0 4.6	155.68 155.48 155.78 155.98 155.08 156.18	
2+31		Drive		4.7	156.08				
2		54 4.3	44 29 5.7 5.2	24 5.0	5 5.6	0 4.9	154.48 155.08 155.58 154.78 155.18 155.88		
1		53 5.7	40 29 6.2 5.7	21 5.5	4 5.7	0 5.3	155.18 154.58 155.08 155.28 154.68 155.48		
0+28		Driveway		5.4	155.38				
0		49 5.2	35 5.6	28 5.6	5 6.7	0 5.4	155.58 155.18 155.18 154.08 155.38		
B.M. 1.		5.38		155.40					







## CONCLUSION.

The fourteen foot width of macadam roadway meets the needs of the present automobile and vehicle traffic on the average state road. While the macadam road will give satisfactory wear for only five or six years, its usefulness is not over when a new road surface is contemplated. The old macadam roads will furnish the base for brick roads, which it is hoped will be used extensively for this work.

The fourteen foot roadway is the most economical and easily constructed. The amount of stone to be handled is not as great as in a wider roadway. During construction of the fourteen foot road, the road need not be closed to traffic, as the shoulders on the side are wide enough to accomodate one wagon on each side. The fourteen foot roadway will allow the passage of two vehicles, with ample space between them so that there is no getting off the road on the dirt with one wheel, whenever two wagons happen to meet, as would happen on a narrower road.

The present solution to the highway problem appears to be the concrete roadway. The sixteen foot concrete roadway on the Springfield - Peoria Road was placed at a cost of about \$8000 per mile. This included heavy grading. The road is in good condition and is very pleasing to the eye. While the concrete road is not the cheapest at first cost, its maintenance is negligible and the facility with which it can be constructed ought to appeal to the road builder.





The type of bridges and roads built by the Illinois Highway Commission supplies the needs of the times. The structures are durable, cheaply and easily constructed and pleasing in appearance. The roads and bridges will take care of the ever changing conditions of traffic for a long time to come.

The present movement, carried to the point where the system of highways is adequate, will result in a tremendous boom to the state. Out of the way places will be developed where hithertofore they have been almost inaccessible and the cost of moving the crops prohibitive. This will give employment to more people and develop the small towns to a greater extent. As this is the only direction in which this state can look forward to for expansion, it means that the future prosperity of the state lies in the hands of the builders of bridges and good roads.



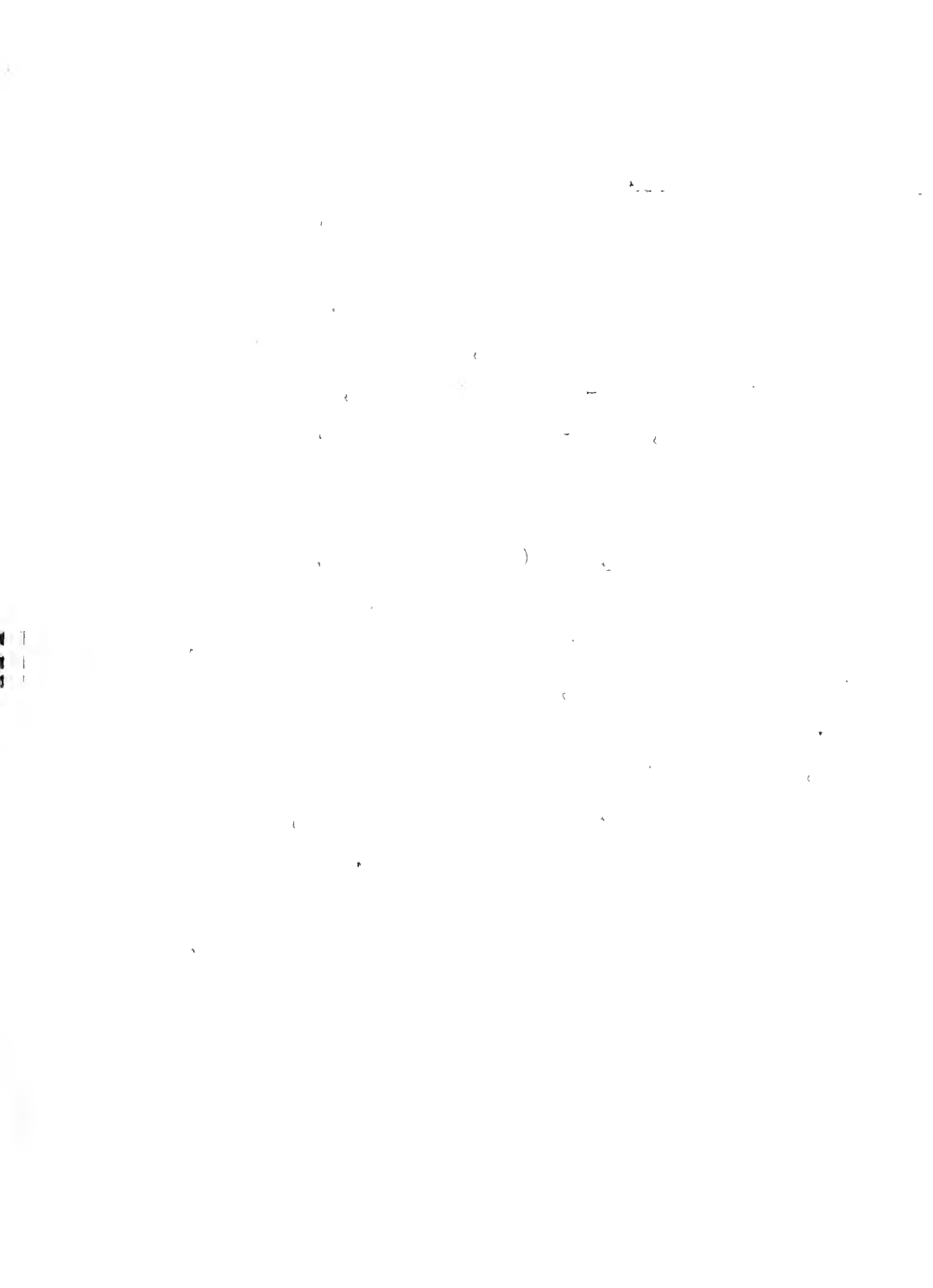
### Cost Data on Road Work.

Accurate data were kept on this work. An itemized statement of material and distribution of labor was made each day on a form which is shown on the next page. From these daily reports the summary was made, which is given in the cost data sheets for the Troy - Collinsville Road, also cost data sheets for Section 3, Troy - Collinsville Road.

### Cost Data on Bridge Work. (Leonard Bridge).

Every day as the work progressed, a daily report card showing the distribution of labor was sent to the office. In addition to the report card, gravel and cement reports were sent in. These show the quality of material which was used on the work, and any deficiency in the material could be easily checked up in the office. The daily report card, gravel and cement card are shown on the following page.

The cost data sheets for the Leonard Bridge show the total and unit costs for the various items on the bridge.



(2041-500)

**GRAVEL REPORT**

Lab. No.

File No.

Name of Br.

Date

Twp.....

Co.

Gravel pit

Test Measurements

Net depth of gravel  
 " " sand  
 " " stone

Sand

Stone

Sand

Gravel

Cu. ft. of stone added per cu. yd. of gravel, if any

Sand

Total Aggregate

Sacks of cement used per cu. yd. of total aggregate

Class ( )

Volumes of total aggregate used per volume of cement

Class ( )

Character of stone

Character of sand

Per cent. clay or loam in sand

Inspector

Address

Inspector

P. O.

1912

Tp. .... Br. .... County ....  
 (2198) 5M INSPECTOR'S DAILY REPORT.

Kind of Work	No. of Hours Worked	Percent Completed	Remarks
Excavating ..			
Abutment ..			
Abutment ..			
Pier ..			
Erecting Forms			
Abutment ..			
Abutment ..			
Pier ..			
Pier ..			
Floor ..			
Girder ..			
Placing Rods			
Concreting ..			
Abutment ..			
Abutment ..			
Pier ..			
Pier ..			
Floor ..			
Girder ..			
Bldg. Flse Wk			
Removing Sums			
Pumping			
Hauling Matrl			
Team and Man			
Remov'g F'rms			
Finishing ..			
Material	Sand	Gvl	Stone
on Ground			Rods
		St'l	Bridge
			Material
Total Men			
Working			
Con. of Stream			
Con of Work			



# ILLINOIS HIGHWAY COMMISSION

## EXPERIMENTAL ROAD CONSTRUCTION

Date

In Charge.

Weather

### DAILY REPORT OF WORK

On	Road, in		Twp.		Co.	
of Work	Township Pay Roll		Subscription List		Crushed Stone Received	
	Men	Teams	Men	Teams	Car No.	Railroad Weight
	Amount	Amount	Amount	Amount		

ience

ad Bed

one on Wagons

one

Stone

Shoulders and  
ds

l Sprinkling

and Miscell-  
labor

nder

nder

Binder

Stone from  
orage Pile

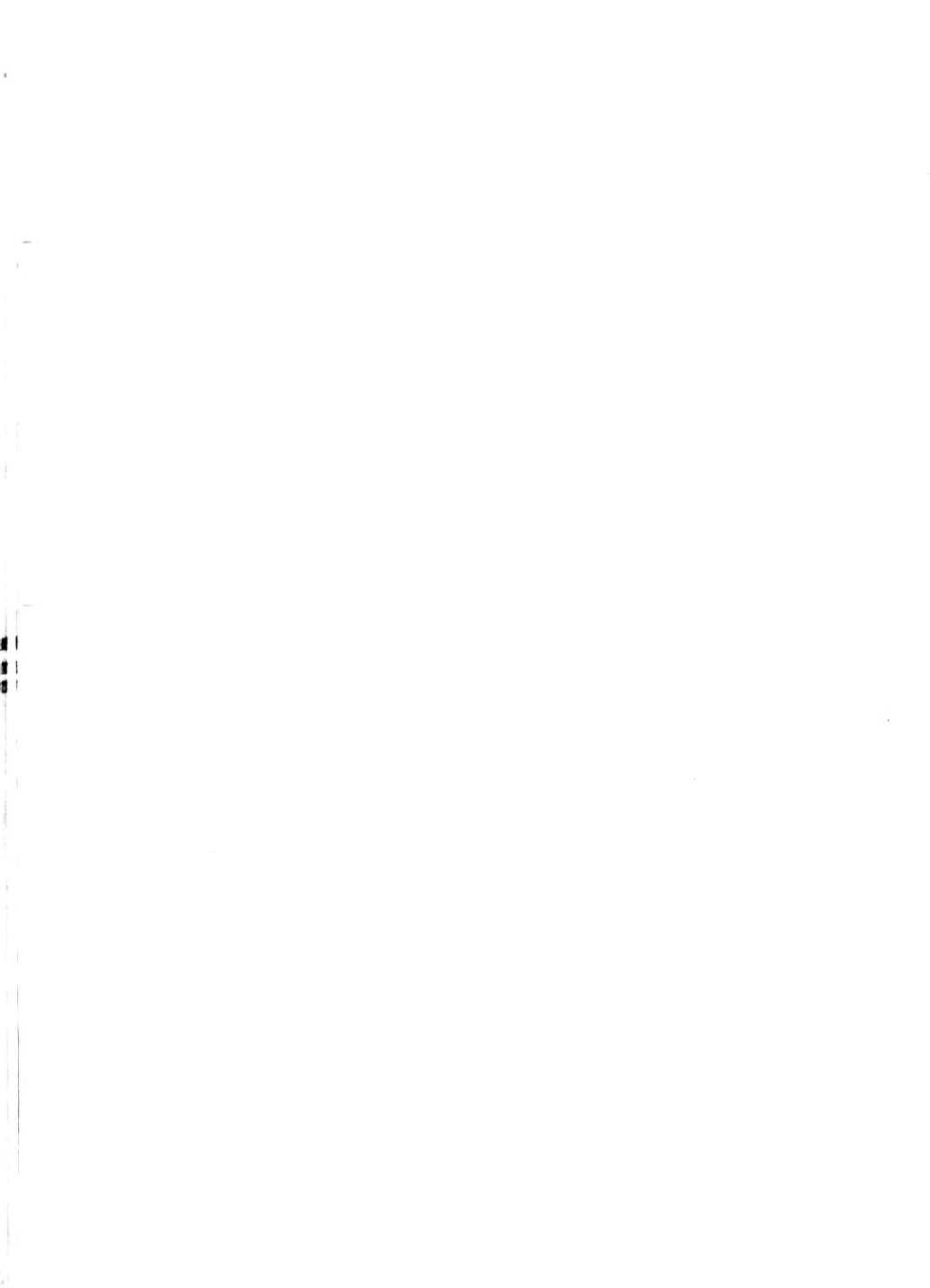
ing

SUPPLIES RECEIVED

Kind	Quantity	Total Cost
------	----------	------------

### W O R K   D O N E

re	From Station	To Station	Hauling	
g			Loads Stone	Mi Cu. Yds.
			Loads Screenings	Mi Cu. Yds.
Lower Course			Loads Gravel	Mi Cu. Yds.
Upper Course			Loads Earth	Mi Cu. Yds.
Sc'g's			Loads Bit Binder	Mi Gallons
Bit Binder			Tanks Water	Mi





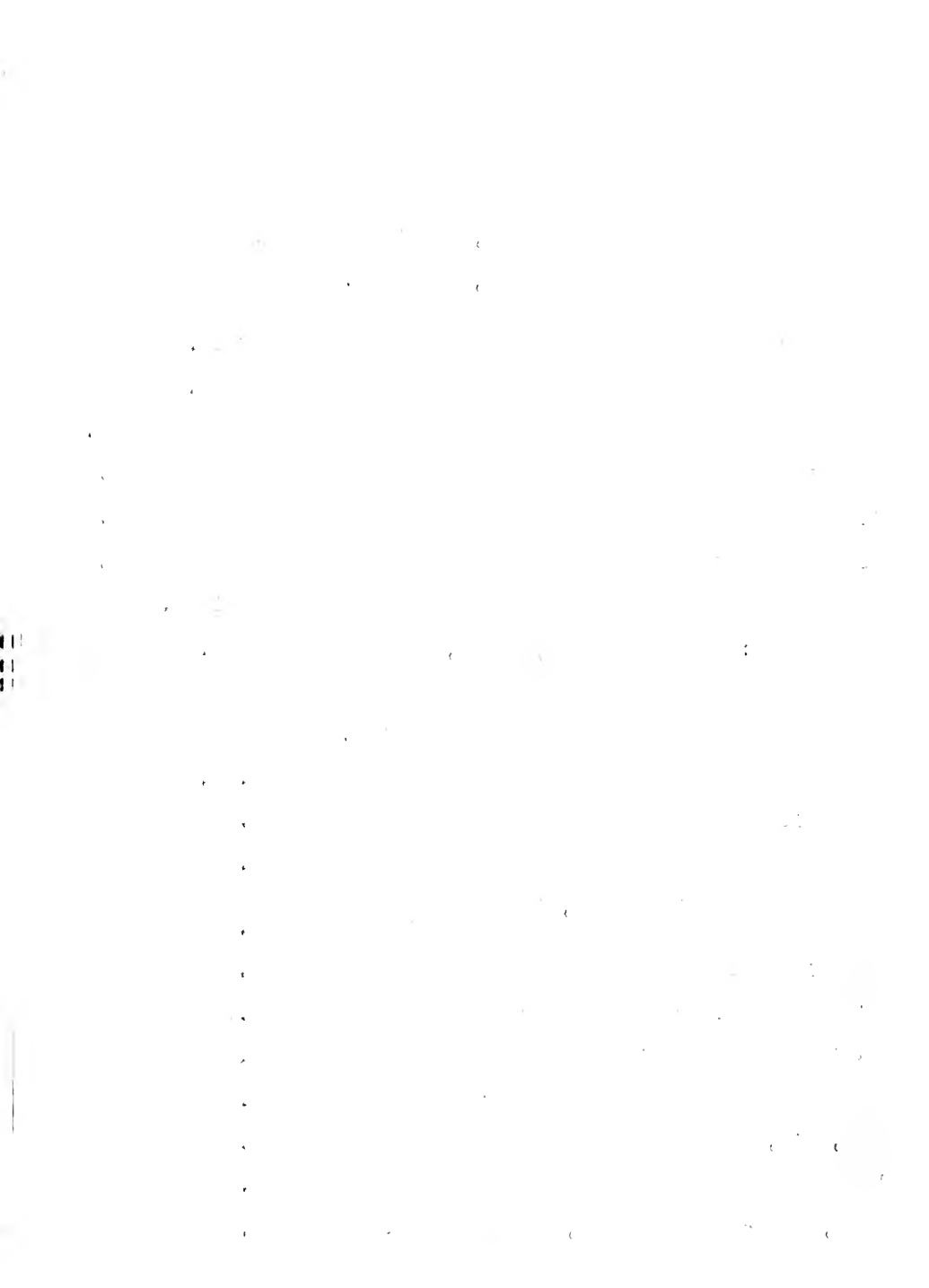
# STATEMENT OF COST OF WORK

Trey - Collinsville Road, Jarvis Township,  
Madison County, Illinois.

Length of road	5280 feet.
Width of macadam	12 feet.
Macadam laid	7040 square yards.
Stone in road	2468 cubic yards.
Stone hauled from cars	2000 cubic yards.
Stone hauled from storage	468 cubic yards.
Average haul of stone	1 $\frac{1}{4}$ miles.
Rate of pay: Men 19 cents; teams, 40 cents per hour.	

## Cost of Labor and Supplies.

Superintendence	\$ 197.50.
Excavation	198.25
Shaping road bed	135.00
Loading and hauling stone, including rehandling	739.58
Spreading stone	188.11
Trimming shoulders and side roads	179.70
Rolling and sprinkling	99.50
Watchman and miscellaneous labor	124.75
Coal, oil, and supplies	56.40
Freight and car service on stone	<u>2423.53</u>
Cost, Labor and Supplies, one mile of road,	4342.32

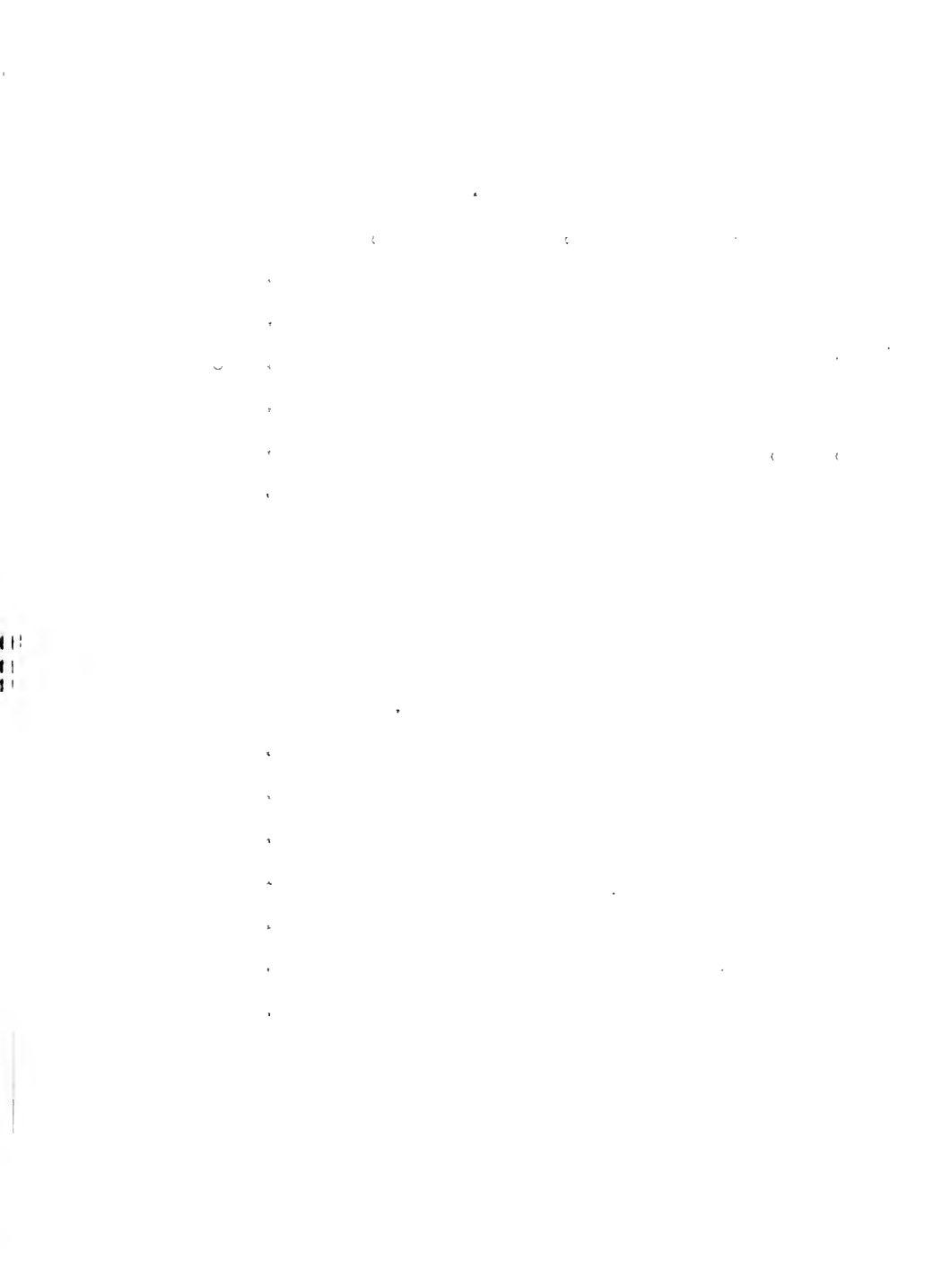


Cost per Cubic yard for  
placing stone.

Unloading stone from cars, hauling stone, including rehandling	\$ 0.3000
Spreading stone	.0770
Rolling and sprinkling	.0403
Watchman and miscellaneous labor	.0503
Coal, oil, and supplies	<u>.0227</u>
Total	\$ 0.4903

Cost per square yard  
Finished Water Bound Macadam.

Superintendence	\$ 0.028
Excavation	.028
Shaping road bed	.019
Trimming shoulders and side roads	.025
Placing stone	.171
Freight on stone	<u>.345</u>
Total	\$ 0.616



# STATEMENT OF COST OF WORK

## Section 3 of Collinsville - Tray Road.

Length of road	5600 feet.
Width of macadam	12 and 14 feet
Macadam laid	8337 square yards
Stone in road	3582 cubic yards
Stone hauled from cars	3000 cubic yards
Stone hauled from storage	582 cubic yards
Average haul of stone	1 mile
Rate of pay: Men, 22½ cents; teams, 50 cents per hour.	

### Cost of Labor and Supplies.

Superintendence	\$ 306.50
Excavation	685.80
Shaping road bed	292.18
Loading and hauling stone, including rehandling	1179.12
Spreading stone	422.88
Trimming shoulders and side roads	135.03
Rolling and sprinkling	256.62
Watchman and miscellaneous labor	235.11
Coal, oil and supplies	34.92
Freight and car service on stone	<u>2176.02</u>
Total	\$ 5774.18



Cost per cubic yard for placing stone.

Loading and hauling stone, including rehandling	\$ 0.329
Spreading stone	.118
Rolling and sprinkling	.072
Watchman and miscellaneous labor	.065
Coal, oil, and supplies	<u>.010</u>
Total	\$ 0.594

Cost per square yard

Finished Water Bound Macadam.

Superintendence	\$ 0.0368
Excavation	0.0824
Shaping road bed	.0344
Trimming shoulders and side roads	.0222
Placing stone	.2555
Freight on stone	<u>.2600</u>
Total	\$ 0.6913





# DETAIL COST OF BRIDGE WORK.

## ACTUAL COST.

Cement.....	170 bbls...@ \$1.00 per bbl. =	\$ 170.00
Hauling cement.....	6 miles..... =	40.00
Sand.....	25.64 cu.yds.@ \$1.35 per c.y. =	34.61
Hauling sand.....	6 miles..@ \$1.50 + (\$4 ext.)=	42.47
Gravel.....	100.3 cu.yds.@ \$1.45 per c.y. =	145.49
Hauling gravel.....	6 miles..@ \$1.50 + (\$8 ext.)=	158.45
Form lumber.....	2,280 M ft.BM.@ \$28 + (\$3.99m/c)=	67.83
Falsework lumber.....	2.8 " " " @ \$28 per M ft. =	78.40
Wire, nails, etc.....	=	18.00
Hauling form lumber.....	6 miles..... =	10.00
Hauling falsework lumber....	6 miles..... =	10.00
Reinforcing steel.....	11220 lbs....@ \$2 cwt + <sup>extra</sup> \$5.75/ =	230.15
Hauling steel.....	6 miles..@ \$1 per ton....=	5.60
Plates.....	122 lbs.)	} .....= 15.00
Rockers.....	250 lbs.)	
Asphalt.....	25 gals...@ \$.08 per gal...=	2.00
Hauling rockers & asphalt...6 miles.....=		2.00
Labor on dry earth excavation.....	=	48.83
Labor on wet earth excavation.....	=	186.96
Cost of pumping during excavation.....	=	10.88
Cost of pumping during concreting.....	=	3.35
Labor building forms.....	=	205.80
Labor building falsework.....	=	106.00
Forward.....	=	\$ 1611.82



# DETAIL COST OF BRIDGE WORK.

## ACTUAL COST (Continued).

Amount forward.....	\$ 1611.82
Labor bending and placing steel.....	77.16
Labor mixing and placing concrete.....	109.93
Labor removing forms.....	17.40
Labor removing falsework.....	10.00
Traveling expenses.....	14.00
Extras.....	<u>37.50</u>
Total.....	\$ 1877.81
Salvage on lumber and falsework.....	<u>100.00</u>
Total net cost to contractor.....	1777.81
Total amount due contractor.....	<u>1535.00</u>
Profit or loss.....	\$ 242.81



# COST PER CUBIC YARD.

Summation of cost per cubic yard for placing 93.2 cubic yards of concrete and 11220 pounds of steel. (This does not include cost of round piling, expansion rockers, or removing old bridge.

Cost per cubic yard of concrete.

Cement.....	170 bbls.....	\$ 2.255
Sand.....	2564 cu.yds.....@ \$2.85 per cu.yd..	.828
Gravel.....	100.3 " " .....@ \$3.15 " " " ..	3.478
Labor on forms per cubic yard of concrete.....		2.395
Form materials per cubic yard of concrete.....		.396
Labor on falsework per cubic yard of concrete.....		1.245
Falsework materials per cubic yard of concrete.....		.509
Cost of steel in place per cubic yard of concrete.....		3.433
Cost of mixing and placing concrete.....		1.375
Cost of excavation per cubic yard of concrete.....		<u>2.81</u>

Total.....\$18.724

Cost of excavation per cu.yd. of substructure concrete	2.81
Cost of falsework per cu.yd. of superstructure	1.75
Cost of removing old bridge.....	15.50

## SUMMARY OF QUANTITIES.

Concrete shown on plans, Superstr	31.0 c.y.	Substr.	62.2 c.y.
Reinforcing steel shown on plans	" 7440 lbs.	" 3780	lbs.
Concrete actually used,	" 31.0 c.y.	" 62.2	c.y.
Reinforcing steel actually used	" 7440 lbs.	" 3780	lbs.



STATE OF ILLINOIS  
STATE HIGHWAY DEPARTMENT

Contract Form  
and  
General Specifications  
for  
Bridge Work





# Contract and Specifications

22. For the bridge work as provided in the plans and specifications and named and described in the advertisement and proposal, forming a part of this contract, and attached hereto, all of which are hereby made a part of the contract.

**THIS AGREEMENT**, made and concluded this \_\_\_\_\_ day of \_\_\_\_\_ 19\_\_\_\_, between the county of \_\_\_\_\_ Illinois, by \_\_\_\_\_ and \_\_\_\_\_ supervisors of said county, and the county of \_\_\_\_\_ Illinois, by \_\_\_\_\_ and \_\_\_\_\_ supervisors of said county, said supervisors having heretofore been appointed by the direction of the respective Boards or by the Chairman thereof to represent the said counties in the matter of said bridge work and \_\_\_\_\_, and \_\_\_\_\_ commissioners of the town of \_\_\_\_\_ in the county of \_\_\_\_\_ and \_\_\_\_\_ and \_\_\_\_\_ commissioners of the town of \_\_\_\_\_ in the county of \_\_\_\_\_ Illinois, acting jointly, and known as the party of the first part, and \_\_\_\_\_

his  
their heirs, executors, administrators, successors, or assigns known as the party of the second part.

23. **WITNESSETH:** That for and in consideration of the payments and agreements mentioned in the proposal, hereto attached, to be made and performed by the party of the first part, and according to the terms expressed in the bond referring to these presents, the party of the second part agrees with said party of the first part at his own proper cost and expense, to do all the work, furnish all materials and all labor necessary to do the work in accordance with the plans and specifications hereinafter described, and in full compliance with all of the terms of this agreement and the requirements of the Engineer under it.

24. And it is also understood and agreed that the advertisement, proposal, bond and plans hereto attached, or hereinafter referred to, are all essential documents to this contract and are a part hereof.

25. **IN WITNESS WHEREOF**, The parties hereto have set their hands on the date herein named.

The County of _____ Illinois	The County of _____ Illinois
by _____ Supervisor	by _____ Supervisor
by _____ Supervisor	by _____ Supervisor
by _____ Supervisor	by _____ Supervisor

heretofore appointed by the direction of the respective county boards, or by the chairman thereof, to represent said counties in the matter of said bridge work.

The Commissioners of Highways of the Town of _____ County of _____	The Commissioners of Highways of the Town of _____ County of _____
_____ Commissioner	_____ Commissioner
_____ Commissioner	_____ Commissioner
_____ Commissioner	_____ Commissioner

Party of the first part.

Party of the second part.

# GENERAL CLAUSES

## WORKING DRAWINGS.

26. Before the fabrication of any steel superstructure shall be undertaken, the contractor shall furnish the engineer with two sets of preliminary working drawings, one of which will be retained and the other returned with necessary corrections. The contractor shall then furnish the engineer with three sets of corrected working drawings, one set to be returned approved by the engineer, if found correct, and the others retained. The working drawings, as approved by the engineer, shall constitute a part of these specifications.

27. **Approval.** It is understood that no steel fabrication shall be undertaken before the working drawings have been approved by the engineer. If the drawings should be retained by the engineer for more than ten days at any one time, a corresponding extension of time will be allowed the contractor.

## NAME PLATE

28. A neat and substantial name plate, made of the best quality of cast iron, shall be rigidly attached to the superstructure of each bridge, having a length of 15 feet or more, at such point as the engineer may direct. The plate shall contain the date, the names of the bridge committee and the name of the contractor, the county superintendent of highways and the designer.

## DISCREPANCIES.

29. In the event of any discrepancy between any drawing and the figures written thereon, the figures shall be taken as correct, and in case of any discrepancy between any drawing and the specifications, the specifications are to govern.

## PATENTED DEVICES.

30. The contractor shall indemnify, keep and save harmless the bridge committee from all liabilities, judgment or cost and expenses which may in any wise come against the said bridge committee, on account of any infringement of any patent, by means of the use of any design, material, machinery, device or apparatus used in the performance of this contract.

31. **Terms of Use.** Any plans which contemplate the use of any patent shall be accompanied by a detailed statement of the exact terms under which such patent is to be used, which terms of use shall be uniform and open to all bidders alike.

## WORK TO BE DONE, MATERIALS, AND TOOLS.

32. The contractor shall furnish all materials, tools, machinery, labor and other means of construction to do all work in connection with the construction of the proposed bridge, including the removal of the existing structure (where such exists), all excavation necessary to complete the substructure, and to leave the waterway unobstructed, and the road and bridge site in a neat and presentable condition, in accordance with the accompanying plans and specifications and requirements under them of the engineer.

## LINES AND ELEVATIONS.

33. The general location and elevation of the structure shall be as indicated on the plans, but the contractor shall at his own cost and expense check such location and elevation and will be held responsible for the same and for the detailed dimension of all parts of the work.

## GRADING

34. Unless otherwise provided under the title of "Special provisions", accompanying the proposal, back fill, approach grades and wearing surface are not to be included in this contract.

## NOTICE OF BEGINNING WORK.

35. The contractor shall notify the engineer in writing a reasonable length of time in advance of the date he expects to begin the work and when he expects to be ready to undertake important features of construction, such as placing the first concrete in footings, walls and superstructure, and shall also notify the engineer in writing of the time the work is ready for final inspection.

## **LAWS AND ORDINANCES.**

36. The contractor and those under him shall conduct the work in such manner as to fulfill all requirements of Federal, State, County or Municipal laws and ordinances applying to the work in hand, and he shall take such necessary precaution as will guard against accident or the loss of life.

## **CLEARING UP.**

37. The contractor shall leave the bridge and premises in a neat and presentable condition, and remove and clear up all rubbish and surplus material and leave the waterway unobstructed; and where it has been necessary to remove an old structure, the material from the same shall be piled neatly on the bank, where it may really be loaded on wagons; it being understood that unless otherwise indicated, under the title of "Special Provisions" accompanying the proposal, said material may be used temporarily by the contractor in the erection of the new structure.

## **PAYMENTS.**

38. Upon completion of the work according to the contract, plans, specifications and agreements as determined thereunder by the engineer, the said engineer shall make to the party of the first part a statement setting forth the work done and material furnished by the contractor, together with the amount due the said contractor therefor, and shall certify the same in writing under his hand. The obtaining of the certificate of the engineer as to the work done, and the price thereof, shall be a condition precedent to the right of the contractor to be paid the sums due him under the terms of this contract.

## **BOND.**

39. The contractor shall be required to file a bond in a sum equal to double the amount of this contract; said bond shall be furnished by some reliable surety company approved by the State Department of Insurance, and shall refer to this contract.

40. When Filed. The law requires that said contract and bond to be binding must be executed and filed within ten days after the date of letting or awarding said contract.

## **ENGINEER AS REFEREE.**

41. It is agreed by both parties to this contract that the engineer shall act as referee in all questions arising under the terms of this contract between the parties thereto, and that the decision of the engineer in all such cases shall be final and binding upon both alike.

## **IMPERFECT WORK ON MATERIAL.**

42. All insufficient, imperfect or damaged work or material when pointed out at any time to the contractor by the engineer, or his authorized assistant, shall be remedied immediately and made good, or removed and rebuilt, or replaced to conform to the plans and specifications; and any omission by the engineer or his authorized assistant, to disapprove of or reject any such defective work or material during construction shall not be deemed an acceptance of such work or material, nor shall such omission on the part of the engineer be construed as in any way releasing the contractor from remedying, replacing or making good any defective work or material so as to conform to the plans and specifications.

## **CHANGES IN PLANS.**

43. The right is reserved to make such changes in the plans and specification, as are not otherwise herein provided for, as may from time to time appear necessary or desirable, and such changes shall in no wise invalidate this contract. Should such changes be productive of increased cost to the contractor, a fair and equitable sum therefor, to be agreed upon in writing before such changed work shall have been started, shall be added to the contract price, and in like manner, deductions shall be made.

## **CONTRACTOR'S LIABILITY.**

44. The contractor hereby assumes all risks and liabilities for accidents and damages that may accrue to persons or property during the prosecution of the work by reason of the negligence or carelessness of himself, his agents or his employees.

45. The contractor shall be held responsible for the care of all material, partially completed and finished work, until final completion and acceptance by the bridge committee.

## **SUB-LETTING CONTRACT.**

46. The contractor agrees to give his personal attention to this contract and not to sub-let the same, or any portion thereof, without the written consent of the engineer.

## INSTRUCTIONS TO FOREMEN.

47. The superintendent or foreman of any particular portion of the work shall receive and obey the instructions of the engineer referring to that particular part of the work, in case the contractor himself is not present.

## INCOMPETENT OR DISORDERLY WORKMEN.

48. Any foreman or workman employed by the contractor or by any sub-contractor who, in the opinion of the engineer or his authorized assistant, shall not perform his work in a proper and skillful manner or shall be disrespectful, intemperate, disorderly or otherwise objectionable, shall, at the written request of the engineer, be forthwith discharged by the contractor or sub-contractor employing such foreman or workman, and shall not be employed again on any portion of the work provided for by these plans and specifications without the written consent of the engineer.

## FORCE

49. The contractor shall begin work as specified in the contract, and shall at all times thereafter employ such force and equipment as will, in the opinion of the engineer, be necessary to complete the work within the contract time. Should the contractor fail to begin the work at the proper time, or to maintain such necessary force and equipment, or if it becomes evident to the engineer that the work is not being prosecuted with due diligence, or will not be completed within the contract time, it is hereby understood that the bridge committee, on written notice from the engineer that the work is not making proper progress, may re-let the remaining portion of the work, or employ such additional labor and purchase such additional tools and material as may seem essential to insure the completion of the work within the contract time. The total cost of the work thus done, including the cost of labor, tools and materials, shall be deducted from any moneys due, or to become due the contractor, or covered by the bond for fulfillment of the contract.

## DELAYS.

50. No charge will be made by the contractor for hindrances or delays from any cause whatsoever in the progress of the work, but such hindrances or delays may be held as sufficient reason for an extension of the time allowed for the completion of the work.

## DUTIES OF INSPECTORS.

51. It shall be the duty of the inspector to see that the provisions of the contract and specifications are fulfilled by the contractor; in case all the requirements of the specifications are not fulfilled, to report the same immediately to the engineer. Any suggestions which the inspector may give the contractor shall in no wise be construed as releasing the contractor from the proper fulfillment of the terms of this contract as determined by the engineer. The inspector will perform such other duties as the engineer may indicate.

## DEFINITIONS.

52. **Bridge Committee.** Wherever the word "Bridge Committee" is used in this contract, it is understood to mean the party of the first part of this contract, or their authorized representative limited by the particular duties intrusted to him.

53. **Contractor.** Wherever the word "Contractor" is used, it is understood to mean the person or persons who have entered into this contract as party or parties of the second part or <sup>his</sup> ~~their~~ heirs, executors, administrators, successors or assignees.

54. **Inspector.** Wherever the word "Inspector" is used, it is understood to mean the person employed to perform such duties as are herein described as duties of the inspector.

55. **Engineer.** Wherever the word "Engineer" is used, it is understood to mean the county superintendent of highways of the county in which the work is located, or his authorized representative.

# TYPES OF BRIDGES

56. These specifications include the requirements for bridges located outside of the corporate limits of cities and villages and which are expected to carry highway traffic only.
57. The following types of bridges will be given preference in all cases under the conditions described.

## CONCRETE BRIDGES.

58. **Culverts.** For culverts requiring an area of water-way of 12 square feet or less; plain or reinforced concrete arches, reinforced concrete boxes, reinforced concrete pipe or double strength cast iron pipe.
59. **Small Bridges.** For culverts having a waterway of more than 12 square feet, and for bridges having spans up to 30; reinforced concrete slabs, plain or reinforced concrete arches.
60. **Bridges.** For bridges having spans of 30 feet to 65 feet; reinforced concrete through or deck girders, plain or reinforced concrete arches.
61. For bridges having spans greater than 65 feet; plain or reinforced concrete arches.
62. **Arches.** Plans for plain or reinforced concrete arches will not be approved unless founded on solid rock or unusually firm hard pan, except for paved culverts and very small paved bridges.

## STEEL BRIDGES.

63. **Use Of.** In general, plans for steel bridges will not be approved except for structures spanning drainage ditches, navigable channels, and for locations where the cost of concrete structures would be prohibitive.
64. **Bridges Over Drainage Ditches.** For bridges spanning drainage ditches where it is anticipated that it will be necessary to remove the bridge superstructure periodically to permit the passage of a dredge, pin, or bolted field connections of the type prescribed in sections 274, 275, 320 and 321 shall be used.
65. **Types For Various Spans.** For bridges having spans of 12 feet to 45 feet; steel I beams.
66. For bridges having spans of 30 feet to 100 feet; plate girders or riveted pony trusses.
67. For bridges having spans of 90 feet to 160 feet; riveted trusses with parallel chords.
68. For bridges having spans of 160 feet or more; riveted or pin connected trusses with parallel or inclined upper chords.

## ROADWAYS.

69. In general the clear width of roadways for bridges shall be not less than as follows:
70. **On Designated State Aid Routes.** Bridges up to and including 25 feet in length.....24 feet.
71. Bridges 25 feet and up to and including 60 feet in length.....20 feet.
72. Bridges over 60 feet in length.....18 feet.
73. Length is understood to mean the distance face to face of abutments.
74. Bridges located on designated state aid routes at a distance of more than 10 miles, by direct route from any city having a population of 5,000 or over and at a distance of more than 3 miles from any city having a population of less than 5,000 may provide roadways 20 per cent narrower than prescribed in sections 70 and 71 with a minimum of 18 feet.
75. No bridge shall, however, when located on a designated state aid route within 50 miles of any city having a population of over 200,000 have a clear roadway of less than 24 feet.
76. **On Principally Traveled Roads.** On principally traveled roads, other than designated state aid routes:
77. Bridges and culverts of 8 feet or less in length.....24 feet.
78. Bridges over 8 feet and up to and including 60 feet in length.....18 feet.
79. Bridges over 60 feet in length.....16 feet.
80. No such bridge or culvert shall, however, when located within three miles by direct route of any city or village having a population of 10,000 or over, have a clear width of roadway of less than 24 feet for bridges having a length of 25 feet or less; nor less than 18 feet for bridges having a length of more than 25 feet.
81. **On Secondary Roads.** On lesser traveled or secondary roads:
82. Bridges and culverts of 8 feet or less in length.....20 feet.
83. Bridges over 8 feet in length.....16 feet.
84. **Culverts Under Fills.** When culverts are built under fills, the length of the barrel of the culvert shall be such as to permit of side slopes of two horizontal to one vertical, and in addition, a top width of fill not less than as follows:
85. On designated state aid routes.....25 feet.
86. On principally traveled roads.....25 feet.
87. On secondary roads.....20 feet.

# LOADINGS

88. All parts of all bridge structures shall be designed to carry the dead and live loads herein prescribed without exceeding the allowable stresses hereinafter specified.

## DEAD LOADS.

89. **How Figured.** The dead load shall include the weight of the structure complete, including the weight of the pavement or other wearing surface.

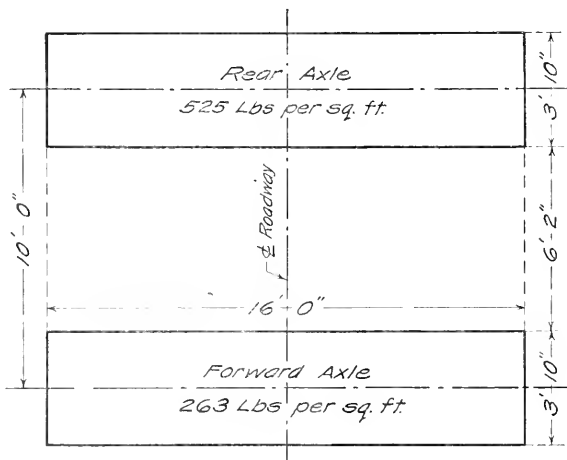
90. **Concrete Floor and Wearing Surface.** All members and details of steel bridges shall be designed to carry a concrete floor slab, assumed to weigh not less than 48 pounds per square foot of roadway surface and a pavement or wearing surface assumed to weigh not less than 50 pounds per square foot.

91. **Weight of Materials.** In computing the dead load, the following unit weights shall be used:

Steel .....	490 lbs. per cu. ft.
Concrete .....	144 lbs. per cu. ft.
Earth fill .....	100 lbs. per cu. ft.
Gravel, tamped .....	120 lbs. per cu. ft.
Macadam and gravel rolled .....	140 lbs. per cu. ft.
Brick .....	150 lbs. per cu. ft.
Yellow Pine and Douglas Fir .....	42 lbs. per cu. ft.
Oak .....	54 lbs. per cu. ft.
Creosoted pine or fir .....	60 lbs. per cu. ft.

## LIVE LOADS FOR CONCRETE BRIDGES.

92. Concrete bridge structures shall be designed to sustain in addition to the dead load, a uniform live load of 125 pounds per square foot of roadway surface, or the concentrated live load indicated in Figure 1. In all cases, the load used and its position on the bridge shall be that which will produce the greatest stress in that part of the structure under consideration.



## LIVE LOADS FOR STEEL BRIDGES.

93. **Concentrated Load.** All floor systems shall be designed to sustain in addition to the dead load, a concentrated live load of not less than 15 tons, which shall be considered as supported on two axles, spaced ten feet apart, the rear axle to carry ten tons and the forward axle 5 tons.

94. **Concrete Floor Slabs.** Concrete floor slabs shall be designed to carry in addition to the dead load, a uniform live load of 1440 pounds per square foot of slab.

95. **Longitudinal Stringers.** Stringers arranged parallel to the axis of the roadway shall be spaced not more than  $2\frac{1}{2}$  feet apart and each stringer shall be designed to carry not less than 20 per cent. of the rear axle load indicated above, considered as concentrated at the center of the stringer span.

96. **Transverse Stringers.** In plate girder bridges when the stringers are arranged at right angles to the axis of the roadway, and are spaced not more than  $2\frac{1}{2}$  feet apart, each stringer shall be designed to carry not less than 40 per cent. of the rear axle load indicated above, considered as uniformly distributed over the middle 10 feet of the stringer.

97. **Uniform Load On Stringers.** Stringers of spans under 50 feet in length shall be designed to carry a uniform live load of not less than 125 pounds per square foot of roadway surface, and of spans over 50 feet in length, 100 pounds per square foot of roadway surface when such uniform live load would produce stresses in excess of those produced by the above concentrated load.

98. **Floor Beams.** Floor beams shall be designed to carry in addition to the dead load, the full concentrated live load specified in section 93, arranged in such position as to produce maximum stresses in the floor beams, or for spans of 50 feet or less, a uniform live load of not less than 125 pounds per square foot of roadway surface, and for spans of greater length than 50 feet, a uniform live load of not less than 100 pounds per square foot of roadway surface, provided such uniform live load would produce greater stresses than the concentrated load described.

99. **Loads For Trusses.** In designing all trusses and plate girders, the following uniform live loads arranged in such position as to produce the maximum stress in the member or detail under consideration, shall be assumed:

100. For spans of 50 feet or less, a uniform live load of 125 pounds per square foot of roadway surface.

101. For spans over 50 feet, up to and including 150 feet, 100 pounds per square foot of roadway surface.

102. For spans longer than 150 feet, 85 pounds per square foot of roadway surface.

103. **Wind Load.** To provide for wind strains and vibrations, all lateral bracing shall be designed for a wind load of 25 pounds per square foot of the vertical projection of the exposed surface of both trusses and the floor system. No such wind load shall, however, be figured at less than 300 pounds per lineal foot of bridge for the loaded chord nor less than 150 pounds per lineal foot of bridge for the unloaded chord.

104. No permanent lateral bracing need be provided in the plane of the loaded chord, provided a solid concrete floor, reinforced in both directions is immediately to be placed on the structure. In this case, however, a temporary lateral system consisting of adjustable rods must be used to hold the chord in line while the floor is being placed. After the floor is completed, such temporary laterals must be removed.

# ALLOWABLE STRESSES

105. The modulus of elasticity of steel shall be taken as 30,000,000 pounds per square inch.
106. The modulus of elasticity of concrete shall be taken as 2,000,000 pounds per square inch.
107. The coefficient of expansion of concrete, plain or reinforced, shall be taken as 0.000,006.
108. The total combined stress in the various parts of any bridge structure shall not exceed the following:

## CONCRETE ABUTMENTS AND PIERS.

109. Tension in concrete.....	00 lbs. per sq. inch.
Compression in Class A. concrete.....	700 lbs. per sq. inch.
Compression in Class B. concrete.....	450 lbs. per sq. inch.
Tension in reinforcing steel.....	16000 lbs. per sq. inch.
Bond between reinforcing steel and concrete (surface area).....	80 lbs. per sq. inch.

## REINFORCED CONCRETE SLAB SUPERSTRUCTURES.

110. Restrained Slabs. Slabs restrained from free expansion or contraction due to temperature changes, by friction on abutments or otherwise:

Tension in concrete.....	00 lbs. per sq. inch.
Compression in concrete (Class A).....	800 lbs. per sq. inch.
Shear (diagonal tension) in concrete when no shear reinforcement is provided.....	40 lbs. per sq. inch.
Shear (diagonal tension) in concrete when reinforcement is provided for shear in excess of 40 lbs. per sq. inch.....	120 lbs. per sq. inch.
Bond between reinforcing steel and concrete (surface area).....	80 lbs. per sq. inch.
Tension in reinforcing steel.....	12000 lbs. per sq. inch.

111. Simple slab bridges when the slab is merely separated from the foundation walls by means of a paper, felt, tar or asphalt joint will not be considered as free to expand or contract.

## REINFORCED CONCRETE GIRDERS

112. Provision For Free Expansion. Reinforced concrete girders shall in every case be provided with rocker or other efficient bearings of nominal friction and all parts of the superstructure shall be completely separated from the foundations by an open joint or a joint not less than  $\frac{1}{4}$  inch thick, filled with bituminous felt.

113. Tension in concrete.....	00 lbs. per sq. inch.
Compression in concrete (Class A.).....	1,000 lbs. per sq. inch.
Shear (diagonal tension) in concrete when no shear reinforcement is provided.....	40 lbs. per sq. inch.
Shear (diagonal tension) when reinforcement is provided for shear in excess of 40 lbs. per sq. inch.....	120 lbs. per sq. inch.
Bond between reinforcing steel and concrete (surface area).....	80 lbs. per sq. inch.
Tension in reinforcing steel.....	16,000 lbs. per sq. inch.
Bearing on expansion rockers (cast iron) resting on steel plates.....	300d lbs. per linear inch.
(d=diameter of rocker in inches.)	

## PLAIN AND REINFORCED CONCRETE ARCHES.

114. Except for three hinged arches, temperature stresses induced by a range of 40 degrees either way from the normal shall be provided for in addition to dead and live load stresses.

115. Tension in concrete.....	00 lbs. per sq. inch.
Compression in concrete (Class A).....	800 lbs. per sq. inch.
Shear (diagonal tension) when no shear reinforcement is provided.....	40 lbs. per sq. inch.
Shear (diagonal tension) when reinforcement is provided for shear in excess of 40 lbs. per sq. inch.....	120 lbs. per sq. inch.
Bond between reinforcing steel and concrete (surface area).....	80 lbs. per sq. inch.
Tension in reinforcing steel.....	16,000 lbs. per sq. inch.



## RESTRAINED STRUCTURES.

116. The stresses specified for "Restrained Slabs" section 110 shall not be exceeded in the design of all reinforced concrete slabs, beams, girders and other parts of the bridge superstructure, when such part is restrained from free expansion and contraction by sliding friction on supports or otherwise.

117. Simple slab structures and T beam superstructures resting directly on the foundations are of this class.

## UNRESTRAINED STRUCTURES.

118. The stresses specified for "Reinforced Concrete Girders" section 113 shall not be exceeded in the design of all reinforced concrete girders, beams, slabs and other parts of the bridge superstructure, when such part may expand and contract practically without restraint by friction on abutments or otherwise.

119. Reinforced concrete girders resting at one end on rockers, floor beams and floor slabs of through or deck girders are of this class.

## STEEL SPANS.

120. **Tension.**  
Medium steel and steel castings-----16,000 lbs. per sq. inch.  
Wrought iron-----13,000 lbs. per sq. inch.
121. **Compression.**  
Compression -----16,000-70  $1/r$  lbs. per sq. inch,  
but not to exceed 14,000 lbs. per square inch.  
 $l$  = unsupported length of member in inches.  
 $r$  = corresponding radius of gyration in inches.  
The greatest  $1/r$  shall not exceed 120 for main truss members nor 140 for lateral or other secondary members.  
Forked ends and extension plates-----10,000-300  $1/t$  lbs. per sq. inch.  
 $l$  = distance in inches from center of pin hole to first rivet beyond point where full section of the member begins.  
 $t$  = thickness of plates.  
Cast steel-----16,000 lbs. per sq. inch.
122. **Bending.**  
Extreme fiber of rolled and built up sections and steel castings, tension  
and compression-----16,000 lbs. per sq. inch.  
Extreme fiber of pins-----24,000 lbs. per sq. inch.
123. **Shear.**  
Shop rivets and pins-----10,000 lbs. per sq. inch.  
Bolts and field rivets-----8,000 lbs. per sq. inch.  
Webs of rolled or built up beams, gross section (average)-----10,000 lbs. per sq. inch.
124. **Bearing.**  
Pins and shop rivets-----20,000 lbs. per sq. inch.  
Bolts and field rivets-----16,000 lbs. per sq. inch.  
Expansion rollers 600 times diameter of roller in inches, per linear inch.
125. **Reversing Stresses.**  
Connections of members carrying reversing stresses shall be proportioned for a stress found by adding  $\frac{3}{4}$  of the lesser to the greater stress.  
**Wind Load, Chord Stresses.**

126. The stresses in the truss members or trestle posts from the assumed wind forces need not be considered except as follows:

127. When the wind stresses in any member exceed 25 per cent. of the maximum stresses due to the dead and live loads upon the member, the section shall be increased until the total stress per square inch will not exceed the combined dead and live load stress by more than 25 per cent.

128. When the wind stress alone or in combination with a possible temperature stress can neutralize or reverse the stresses in any member.

# FOUNDATIONS

129. **Stone masonry and plain or reinforced concrete abutments, piers, and end walls for all bridges and culverts shall be designed in accordance with the best modern practice. So called tube and leg foundations will not be considered.**

130. **Abutments To Be Self Supporting.** Abutments except for reinforced concrete slab bridges shall be designed as self supporting with the approach fills complete in place.

131. **Drainage.** Adequate drainage for the backs of abutments and wings shall be provided by tile or other pipe drains running through the walls at the lowest elevation possible which will provide free outlets.

132. **Batter.** The batter on the face of all plain concrete walls and piers shall be not less than  $\frac{1}{2}$  inch to 1 foot.

133. **Footings.** The footing width of all plain and reinforced concrete abutments, wing and retaining walls shall be not less than one-third of the height of the wall.

134. **Depth Of Footings.** Footings shall be carried down below stream bed a minimum distance of 4 feet unless rock or unusually compact hard pan is encountered at a lesser depth, except for spans under 12 feet in length in which case a heavily reinforced floor may be used to distribute the load on the foundation.

135. **Loads On Footings.** Footings, floors of paved culverts and abutment walls shall be so designed as to distribute the loads over the full length and width of the main wall foundations.

The pressure on ordinary soils shall not exceed 1.5 tons per square foot average, for abutment wing or pier footings. Wing footings shall not be considered as taking any of the superstructure load.

136. **Cofferdam.** Suitable and practically water tight cofferdams preferably of steel sheet piling or tongue and groove wood piling shall be used whenever water bearing strata are encountered above the elevation of the bottom of the excavation.

137. **Pumping.** Pumping will not be permitted from the inside of foundation forms while concrete is being placed, and if necessary to prevent flooding, a seal of concrete shall be placed through a chute or by means of bottom dump buckets, and allowed to set.

138. **Placing Concrete Under Water.** Concrete shall not be placed in running water and shall only be placed in still water with suitable appliances and under the direction of the engineer.

139. **Dimensions Of Pits.** The inside dimensions of pits and cofferdams shall be sufficiently large to give easy access to all parts of foundation forms.

140. **Reinforced Abutments.** In properly designed reinforced concrete abutments when the wing walls are located at an angle of 45 degrees or more with the face of the abutment wall, advantage may be taken of the mutual support afforded by the main and wing walls when properly tied together by reinforcing steel.

141. All parts of such abutments shall be designed to resist a pressure, imposed upon the vertical projection of all walls, figured as that which would be caused by a fluid having the same depth as that of the earth fill and considered as weighing not less than 15 pounds per cubic foot.

142. Retaining walls, reinforced concrete abutments and wing walls, when the wing walls make an angle of less than 45 degrees with the face of the abutment, shall be designed to resist a pressure, imposed upon the vertical projection of such walls, figured as that which would be caused by a fluid having the same depth as that of the earth fill and weighing not less than 21 pounds per cubic foot. In this case the width of footing shall not be less than 0.4 of the height of the wall.

143. In designing reinforced concrete abutments for slab bridges, it may be assumed that the slab of the superstructure supports the top of the main wall as regards the overturning effect of earth pressure.

144. Footings of reinforced concrete abutments, wing walls and retaining walls shall be so proportioned that the resultant of all forces, including the weight of concrete, weight of earth fill directly over the footing, weight of superstructure (on main wall only) and the horizontal equivalent fluid pressure, shall fall at or back of the forward edge of the middle third of the footing base.

## EXTRA FOUNDATION WORK.

145. Should it be found necessary to carry the foundations to a depth exceeding three feet below that shown on the plans, the contractor shall be paid, in addition to the contract prices stated in the proposal, an amount equal to the cost of completing that part of the foundation below said three feet, plus 15 per cent. of said cost.

146. **Cost.** Cost shall be considered as made up of the cost of materials, plus the actual cost of the labor, but shall not include any charge for overhead, rental, depreciation of equipment, or other expense.

147. **Maintaining Batter.** Should it be found necessary in the judgment of the engineer to increase or decrease the depth of the foundations from that shown on the plans, the thickness of the wall, where said wall joins the footing, shall be increased or decreased the same amount per foot as the main wall increases per foot of its height as shown on the plans.

# SPECIFICATIONS FOR CONCRETE

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148. It is understood that all prices for concrete masonry shall include furnishing all materials, necessary forms and falsework, tools, labor, excavation and incidental work necessary properly to place the concrete.

## PLANS AND DIMENSIONS.

149. All concrete masonry shall be built to the dimensions as shown on the plans furnished or approved by the engineer, and which are a part of these specifications.

150. The concrete shall be of the character indicated on the plans or as provided for in these specifications, and shall be built by the contractor in accordance therewith.

## CEMENT.

151. The cement shall be a standard brand of Portland cement which has been in practical use on public works for not less than three (3) years, and shall have proved satisfactory therein. No brand shall be used which the engineer deems unfit for the work or which does not conform to the requirements of the specifications of the American Society for Testing Materials, as adopted August 16, 1909, when tested in accordance with the methods proposed by the Committee on Uniform Tests of Cement of the American Society of Civil Engineers presented at the society January 21, 1903, amended January 20, 1904, and January 15, 1908, with all subsequent amendments thereto.

152. One bag of cement will be considered as having a volume of 0.95 cubic feet.

153. The contractor shall notify the engineer in writing what brand or brands he intends to use, and before ordering the cement shall receive the written approval of the engineer as to the brand selected. It is understood that such approval merely covers the selection of the brand; that the cement itself may be rejected if it fails to meet the requirements herein specified.

154. **Protecting Cement.** The contractor shall provide sufficient means to protect the cement against dampness, and no cement shall be used which has become caked.

## WATER.

155. Clean water shall be used in mixing concrete and shall be free from oils, acids or alkalis.

## SAND.

156. Sand shall be composed of clean, coarse quartz, or other equally hard and durable grains, passing, when dry, a screen having  $\frac{1}{4}$  inch openings.

157. The grains shall be graded in size from fine to coarse, but not more than 15 per cent by volume shall pass a sieve having 50 meshes to the inch. It shall not contain more than 3 per cent by dry volume of clay.

158. Sand containing organic matter shall not be used in the work.

## STONE.

159. Stone used for concrete work shall consist of crushed rock or gravel stones screened to the sizes herein specified and shall consist of clean, sound, hard and durable material.

No weathered or disintegrated material shall be used.

## PROPORTIONS.

160. **Classes.** Unless otherwise specially indicated on the plans, there will be three classes of concrete known as class X, class A and class B.

161. **Class X.** Class X concrete shall consist of 1 part cement, 2 parts sand and not to exceed  $3\frac{1}{2}$  parts stone, which will be retained on a  $\frac{1}{4}$  inch screen and which will pass a 1 inch ring. At least 40 per cent of the stone shall be retained of a  $\frac{1}{2}$  inch screen.

162. **Class A.** Class A concrete shall consist of 1 part cement,  $2\frac{1}{2}$  parts sand and not to exceed 4 parts stone which will be retained on a  $\frac{1}{4}$  inch screen and which will pass a  $1\frac{1}{2}$  inch ring. At least 50 per cent of the stone shall be retained on a  $\frac{1}{2}$  inch screen.

163. **Class B.** Class B concrete shall consist of 1 part cement, 3 parts sand and not to exceed 5 parts rock broken to pieces which will be retained on a  $\frac{1}{4}$  inch screen and which will pass a  $2\frac{1}{2}$  inch ring. At least 50 per cent of the stone shall be retained on a 1 inch screen.

### UNSCREENED GRAVEL.

164. Unscreened gravel may be used for concrete in the place of broken stone and sand.

165. **Testing.** When so used, frequent tests will be made to determine the relative proportions of sand and stone, and in case the relative proportions of sand and stone are excessively irregular so as to make it practically impossible to proportion the concrete properly, the engineer may require the material to be screened and reportioned.

166. **Sand.** Sand shall be considered as that portion of the gravel which passes a  $\frac{1}{4}$  inch screen and shall conform to the requirements herein specified for sand.

167. **Stone.** Stone shall be considered as that portion of the gravel retained on a  $\frac{1}{4}$  inch screen and shall conform to the requirements herein specified for stone.

168. **Cement.** In all cases when unscreened gravel is used, 1 part by volume of cement shall be used to each 2 parts of sand, contained in the gravel, for class X concrete; 1 part of cement to  $2\frac{1}{2}$  parts of sand for class A concrete and 1 part of cement to 3 parts of sand for class B concrete.

169. **Adding Stone.** In case the ratio of the volume of sand to the volume of stone is greater than the minimum indicated above under "Proportions," stone may be added in sufficient quantity to reduce this ratio to the minimum stated for each class of concrete.

### RUBBLE CONCRETE.

170. In any class B concrete when used in plain concrete piers, abutments and retaining walls, having sections two (2) feet thick or more, "one man" stone may be used. When such stone is used, it must be clean, sound and hard and each piece shall be completely surrounded by a layer of concrete not less than six (6) inches thick.

171. **Stone from Old Bridge.** Unless otherwise provided in the special provisions accompanying the proposal, suitable stone removed from the old structure, when such structure is to be removed by the contractor, may be used for this purpose.

### MIXING.

172. **Batch Mixer.** Concrete shall be mixed in a batch mixer, approved by the engineer.

173. **Tempering.** Sufficient water shall be used in mixing the concrete so that the water will readily flush to the surface with light spading or troweling. An excess of water causing more than a slight accumulation above the surface of the concrete will not be permitted.

174. **Retempering.** Concrete shall be mixed in such quantities that a batch can be placed in the work within 30 minutes from the time of mixing. No concrete which has taken an initial set, and which requires rettempering, shall be used.

### PLACING.

175. All concrete shall be carefully deposited in place in such a manner that the stone and mortar are not separated.

176. **Spading.** As fast as concrete is deposited, it shall be thoroughly settled by spading or other means to bring the mortar in thorough contact with the forms and reinforcing steel.

177. **Placing in Layers.** Concrete shall be placed in continuous horizontal layers in walls and girders. No plane of set will be allowed at a distance of less than 18 inches below the top of walls or girders. In floors the concrete shall be placed for the full thickness, and the construction of the floor carried along in this manner.

178. **Continuous Placing.** If possible, the entire floor slab of each span shall be poured continuously.

179. **Joints in Floor Slabs.** If joints in floor slabs are necessary, they shall be made in vertical planes located perpendicular to the main reinforcing steel and near the middle of the slab span, except for concrete floors on steel bridges, in which case the joint shall be vertical at right angles to the axis of the roadway and over the center of a floor beam.

180. **Joints in Walls.** If at any time the work is interrupted so that the concrete already deposited has attained final set, the surface of such concrete shall be chipped off for a sufficient depth to expose the coarse aggregate, the loose material swept or washed away, the surface thoroughly wetted, and flushed with a thin 1 to 2 mortar before concreting is resumed.

181. If the work is interrupted so that the last layer of concrete is deposited more than twenty-four (24) hours before the next can be laid, and there are no reinforcing rods projecting, a timber eight (8) inches wide shall be laid the entire length of the course and shall be bedded for at least four (4) inches in the concrete and allowed to remain until the concrete has set. When the work of laying concrete is again resumed, the timber shall be removed and the surface of the concrete shall be cleaned and flushed as above indicated.

182. **Protecting Concrete While Curing.** Concrete floors on steel bridges shall be kept protected from the direct rays of the sun by means of canvas, straw or other means approved by the engineer, and shall be kept continually wet for a period of one week after placing the same.

183. **Freezing Weather.** Concrete to be left above the surface of the ground or water shall not be constructed during freezing weather except on the express written consent of the engineer, and it shall be protected in the manner ordered by the engineer. In this case, water and broken stone shall be heated; and in severe cold, salt shall be added in the proportion of about two (2) pounds per cubic yard, but no salt shall be used for reinforced concrete. It is understood, however, that any concrete laid during freezing weather shall be entirely at the risk of the contractor, and concrete showing injury by frost shall be removed and replaced at the expense of the contractor.

## FORMS.

184. **Furnishing Material.** The contractor shall provide all necessary material and means for building the forms for all concrete masonry.

185. **Construction.** All forms shall be so constructed as to be held rigidly to place, line and elevation. If at any point of the work, after the concrete has been placed, the forms show signs of bulging or sagging, that portion of the concrete shall be immediately removed on notice by the inspector, and the forms shall be properly supported.

186. The amount of concrete to be removed shall be determined by the inspector, and no extra allowance shall be made to the contractor for such work.

187. All forms are to remain in place until in the opinion of the engineer it is safe to remove them.

188. **Moulding.** Moulding having  $\frac{3}{4}$  inch or 1 inch sides shall be used on all exposed corners. The surface of such moulding in contact with the concrete may be rounded to a uniform radius or may be flat. In the latter case the resulting angles between adjacent surfaces in the finished concrete shall be equal.

189. **Bevelled Faces.** Forms shall be given a bevel of 1 inch to 1 foot wherever projections of the concrete, such as copings, floor beams, etc., would otherwise cause binding upon the removal of the forms. The pitch shall be so arranged as to increase the thickness of copings, floor beams, etc., at the base, and the narrowest parts of such projections shall have dimensions not less than as shown on the plans.

## FINISH.

190. **Removal of Forms.** The forms covering what will be the exposed face of the concrete masonry shall be removed as soon as the engineer decides that it is safe to do so, and all crevices neatly filled with a stiff 1 to 2 cement mortar thoroughly rammed into place.

191. All exposed faces shall be brought to a smooth, neat surface by rubbing with a block of wood and sand or a carborundum brick, while the concrete is green.

192. **Mortar Surfaces.** All top surfaces, such as the top of retaining walls, abutments, girders, floors, etc., shall be treated by tamping and troweling in such a manner as to flush the mortar to the surface and provide a smooth, even surface, free from pits and porous places.

193. If necessary to secure such a surface, a thin layer of mortar consisting of one part of cement to two parts of sand shall be applied evenly and troweled smooth before the concrete has set.

## USE OF CLASS B CONCRETE.

194. Unless otherwise specified, class B concrete shall be used in all plain concrete abutments, piers and wing walls, and shall also be used elsewhere as may be provided for on the plans or by the written directions of the engineer.

## USE OF CLASS A CONCRETE.

195. All reinforced concrete, and all plain concrete masonry measuring less than 10 inches in thickness, except for the floors on steel bridges, shall be made of class A concrete unless otherwise shown on the drawings or directed in writing by the engineer.

## USE OF CLASS X CONCRETE.

196. Unless otherwise specified, class X concrete shall be used for all parapet walls, bridge seats and floors on steel bridges.

# SPECIFICATIONS FOR REINFORCING STEEL AND EXPANSION DEVICES

## REINFORCING STEEL.

197. **Type of Reinforcing Steel.** Unless otherwise shown on the drawings, all steel for reinforcement in concrete shall consist of plain square section bars or deformed bars of a type to be approved by the engineer.

198. **Size of Bars.** The size of all steel reinforcement as indicated on the drawings is the size of a square equivalent to the required net section.

199. **Placing.** The steel bars shall be distributed in the concrete in the exact positions and have the net sectional area provided in the drawings. In general, they shall be securely wired or otherwise fastened in place before concrete is deposited.

200. **Material.** Unless otherwise specified, all steel for reinforced concrete shall be mild or medium steel with an elastic limit of not less than 32,000 pounds per square inch. Steel bars shall stand bending cold with a radius equal to twice their diameter through 180 degrees without fracture.

201. **Rerolled and High Carbon Steel.** No rerolled material or high carbon steel shall be used on the work.

202. **Lengths.** All bars must be obtained in the full length indicated on the plans.

203. **Cleaning.** Before steel is placed in the concrete, it shall be free from grease, dirt or rust, and the contractor shall provide means on the work for properly cleaning the steel.

204. **Bedding.** Special care shall be exercised to insure thorough contact of the concrete with every portion of the surface of the steel reinforcement.

## EXPANSION DEVICES.

205. Unless otherwise shown on the plans, all reinforced concrete through or deck girder bridges, classed and designed as unrestrained structures shall be provided with expansion rockers at one end of each span.

206. **Rockers.** The rockers shall be made of cast iron of the kind and quality specified in section 311. They shall have a thickness at least equal to  $\frac{1}{4}$  of the diameter; shall have bearing surfaces turned to a uniform radius and smooth surface and shall be provided with two 2 inch holes through the web to facilitate handling.

207. **Bearing Plates.**—The rockers shall turn between mild or medium steel plates not less than 1 inch thick. The bearing surfaces of the plates shall be planed. The cut of the tool shall be in the direction of the expansion.

208. The plates shall be set in full mortar beds and accurately leveled.

209. **Rocker Pockets.** Pockets two inches longer than the rockers shall be provided in the abutments and piers to receive the lower plates and the rockers. The lower plates shall be placed so that the top of the rockers will be  $\frac{1}{4}$  inch above the surface of the concrete.

210. **Placing Rockers.** The rockers shall be placed accurately at right angles to the axis of the girders and supported in position by short soft wood wedges not more than 1 inch wide placed between the ends of the rockers and the pockets. The wedges shall be soaked in water previous to driving and shall be driven only a sufficient amount to support the rockers in a vertical position. The pockets shall then be completely filled with asphalt of the quality herein specified.

211. The top plates shall be placed in contact with the rockers and carefully leveled. The top plate may be supported by sticks having a cross section of not more than 1 inch and placed vertically, one on each side of the rocker and resting on the bottom of the pocket.

212. The bituminous felt cushion used to separate the superstructure concrete from that of the substructure shall then be placed in such manner as to lap over the top plate not more than 1 inch at each edge.

213. In placing concrete over the rocker pockets, care shall be used to prevent the concrete from entering the pocket. The concrete shall be in contact with the top plate except for the margin of not more than 1 inch covered by the felt at the edges.

214. **Asphalt for Rocker Pockets.** The asphalt used for filling the rocker pockets shall conform to the following requirements:

Coal tar pitch shall not be used under any condition.

215. The specific gravity of the asphalt at 25 degrees C shall be not less than 0.965 nor more than unity.

216. The bituminous material shall be soluble in chemically pure carbon-bisulphide to the extent of at least 99.5 per cent by weight at air temperature.

217. When 20 grams (in a tin dish  $2\frac{3}{8}$  inches in diameter and  $\frac{3}{4}$  inch deep with vertical sides) are maintained at a temperature of 163 degrees C for 5 hours in a New York testing laboratory oven, the loss by evaporation shall not exceed 5.0 per cent by weight, and the penetration of the residue shall not be decreased more than 40 per cent from that of the original sample.

218. The penetration of the asphalt as determined with the Dow machine, using a No. 2 needle, 100 grams weight, 5 sec. time and a temperature of 25 degrees C shall be not less than 15.0 mm nor more than 20.0 mm.

219. **Bituminous Felt.** Bituminous felt, when used to separate the superstructure from the substructure of concrete girder bridges, and when used to separate adjacent superstructures of multiple span concrete girder bridges, shall be provided in pieces, each piece having a thickness of not less than  $\frac{1}{4}$  inch.

Ordinary tarred or plain building paper shall not be used except for separating the superstructure from the foundations of reinforced concrete slab bridges.

# SPECIFICATIONS FOR STEEL BRIDGES

## General Features

220. **Kind of Material.** The material in the superstructure shall be medium steel as hereinafter specified, except for rivets, and as may otherwise be indicated.

221. **Length of Span.** In calculating stresses, the length of span shall be understood to be the distance between centers of end pins or bearings for trusses, center to center of trusses for cross floor beams, and between centers of bearing plates for all longitudinal beams and girders.

222. **Truss Designs.** All trusses shall be so designed as to permit of the accurate calculation of all stresses by the usual methods.

223. **Depth Ratios.** Trusses shall, preferably, have a depth of not less than one-tenth of the span. Plate girders and rolled beams, used as girders, shall, preferably, have a depth of not less than one-twelfth of the span. If shallower trusses, girders or beams are used, the section shall be increased so that the maximum deflection will be not greater than if the above limiting ratios had not been exceeded.

224. **Pony Trusses.** The top chord of low trusses shall be securely braced at the panel points by means of knee braces or solid webbed vertical posts rigidly connected to the floor beams. The outstanding legs of angles used for vertical posts shall not be less than three (3) inches.

225. **Minimum Sizes.** The minimum thickness of metal shall be 5-16 inch except for fillers. The webs of beams and channels shall be not less than  $\frac{1}{4}$  inch thick.

226. No beam or channel less than 6 inches or angle having one or both legs less than  $2\frac{1}{2}$  inches shall be used, except as hereinafter provided.

227. **Clearance.** For all through bridges there shall be a clear head room of not less than fifteen (15) feet above the crown of the finished roadway.

228. The clear roadway shall be taken as the clear distance between trusses.

229. **Plank Floor.** If a temporary untreated plank floor is required there shall be three 4-inch by 6-inch first-class white or burr oak nailing pieces bolted to the outside joists and the middle joist by  $\frac{5}{8}$  inch bolts spaced not more than three (3) feet apart.

230. **Flooring** shall be first-class white or burr oak plank, three inches thick and ten to twelve inches wide, laid heart side down; and shall be spiked to the nailing pieces by three 5-inch wire spikes to each intersection. The planks shall be sawed to uniform length, and shall be laid with their ends in a straight line.

231. **Guard Fences.** Unless otherwise provided for on the drawings, the bridge shall be provided with a guard fence, consisting of two 5-inch 6.5 lb. steel channels on each side. The lower edge of the lower channel shall be 16 inches above the top of the felloe guard and there shall be a 12-inch space between the channels.

232. The guard channels shall be rigidly attached to the posts and diagonals in such a manner as to secure a straight alignment of the channel, and they shall have a length equal at least to the length, center to center, of end pins or bearings.

233. Flanges of guard channels at the ends of the bridge shall be neatly rounded off to a quadrant having a radius of 2 inches.

234. **Concrete Floor.** If a concrete floor is called for in the plans, it shall consist of class X concrete as herein specified.



## Details of Design

235. **Field Connections.** Unless otherwise shown on the plans, all field connections other than pin connections, except for stringers bearing on the top flange of floor beams, and hand rails, shall be riveted.

236. **Stringers.** Stringers bearing on the top flange of floor beams shall be bolted to the floor beams and hand channels, where provided for, by 2 1/2-inch bolts at each end.

237. **Open Sections.** Structures shall be so designed that all parts will be accessible for inspection, cleaning and painting.

238. **Pockets.** Pockets or depressions which would hold water shall have drain holes, or be filled with waterproof material.

239. **Symmetrical Sections.** Main members shall be so designed that the neutral axis will be as nearly as practicable in the center of the section, and the neutral axes of intersecting main members of trusses shall meet at a common point.

240. In pin connected members, where the pins are placed more than 1/2 inch from the neutral axis, the bending effect, due to the eccentricity of pins, shall be provided for.

241. **Counters.** Rigid counters are preferred; and where subjected to reversal of stress shall preferably have riveted connections. Adjustable counters shall have open turnbuckles.

242. The area of counters shall be determined by taking the difference in areas required by the live and dead load stresses considered separately.

243. **Combined Stresses.** When any member is subjected to the action of both axial and bending stresses as in the case of chords carrying distributed floor loads, it must be proportioned so that the greatest fibre stress will not exceed the allowed limits of tension or compression on that member.

244. If the fibre stress resulting from the weight only, of any member, exceeds ten per cent of the allowed unit stress on such member, such excess must be considered in proportioning the area.

245. **Net Section at Rivets.** In proportioning tension members the diameter of the rivet holes shall be taken 1/8 inch larger than the nominal diameter of the rivet.

246. The rupture of a riveted tension member is to be considered as equally probable, either through a transverse line of rivet-holes or through a diagonal line of rivet-holes, where the net section does not exceed by 30 per cent the net section along the transverse line.

247. The number of rivet-holes to be deducted will be determined by this condition.

248. **Rivets.** In proportioning rivets the nominal diameter of the rivet shall be used.

249. **Net Sections at Pins.** Pin-connected riveted tension members shall have a net section through the pin-hole at least 25 per cent in excess of the required net section of the body of the member, and the net section back of the pin-hole parallel with the axis of the member, shall be not less than 80 per cent of the required net section of the body of the member.

250. **Angle Splices.** Both legs of angles carrying tension shall be connected. The number of rivets in each leg shall be in proportion to the net area of metal in that leg.

251. **Proportioning Plate Girders.** Plate girders and built up beams and stringers shall be proportioned by assuming that the flanges are concentrated at their centers of gravity; one-eighth of the net section of the web, if properly spliced, may be used as flange section.

252. **Compression Flanges.** In beams and plate girders the compression flanges shall be made of the same gross section as the tension flanges.

253. **Flange Rivets.** The flanges of plate girders shall be connected to the web with a sufficient number of rivets to transfer, in a distance equal to the effective depth of the girder, the total shear at any section together with any load that is applied directly on the flange.

254. **Web Plates.** The webs of plate girders must be stiffened at intervals, not exceeding the depth of the girders or a maximum of five (5) feet, wherever the shearing stress per square inch exceeds the stress allowed by the following formula:

255. Allowed shearing stress 12,500-90 H, where H=ratio of depth of web to its thickness; but no web plate shall be less than 5-16 inch in thickness.

256. **Stiffeners.** All stiffeners must be capable of carrying the maximum vertical shear without exceeding the allowed unit stress found by the formula:  $P = 12,000 - 55 \frac{1}{r}$ .

257. Each stiffener must be connected to the web by enough rivets to transfer the maximum shear to or from the web.

258. **Rolled Beams.** Rolled beams shall be proportioned by their moments of inertia.

259. **Pitch of Rivets.** The minimum distance between centers of rivet holes shall be not less than three (3) diameters of the rivet; but the distance shall preferably be not less than 3 inches for 3/8 inch

rivets,  $2\frac{1}{2}$  inches for  $\frac{3}{4}$  inch rivets, and  $2\frac{3}{4}$  inches for  $\frac{5}{8}$  inch rivets. The maximum pitch in the line of stress for members composed of plates and shapes shall be not more than six (6) inches for  $\frac{7}{8}$  inch rivets, five (5) inches for  $\frac{3}{4}$  inch rivets, nor more than 16 times the thickness of the thinnest outside plate. For angles with two gauge lines and rivets staggered, the maximum shall be twice the above in each line. Where two or more plates are used in contact, rivets not more than 12 inches apart in either direction shall be used to hold the plates well together. In tension members composed of two angles in contact, a pitch of 12 inches will be allowed for riveting the angles together.

260. **Edge Distance.** The minimum distance from the center of any rivet-hole to a sheared edge shall be  $1\frac{1}{2}$  inches for  $\frac{7}{8}$  inch rivets,  $1\frac{1}{4}$  inches for  $\frac{3}{4}$  inch rivets and  $1\frac{1}{8}$  inches for  $\frac{5}{8}$  inch rivets, and to a rolled edge  $1\frac{1}{4}$  inches,  $1\frac{1}{8}$  and 1 inch respectively. The maximum distance from any edge shall be eight (8) times the thickness of the plate, but not to exceed five (5) inches.

261. **Maximum Diameter.** The diameter of the rivets in any angle carrying calculated stress shall not exceed one-quarter of the width of the leg in which they are driven. In minor parts  $\frac{7}{8}$  inch rivets may be used in 3 inch angles, and  $\frac{3}{4}$  inch rivets in  $2\frac{1}{2}$  inch angles.

262. **Long Rivets.** Rivets carrying calculated stress and whose grip exceeds four (4) diameters shall be increased in number at least one (1) per cent for each additional 1-16 inch of grip.

263. **Pitch at Ends.** The pitch of rivets at the ends of built up compression members shall not exceed four (4) diameters of the rivet, for a length equal to one and one-half times the maximum width of the member.

264. **Compression Members.** In compression members the metal shall be concentrated as much as possible in webs and flanges. The thickness of each web shall be not less than one-thirtieth of the distance between its connection to the flanges. Cover plates shall have a thickness not less than one-fortieth of the distance between rivet lines.

265. **Minimum Angles.** Flanges of girders and built up members without cover plates shall have a minimum thickness of one-twelfth of the width of the outstanding leg.

266. **Tie Plates.** The open sides of compression members shall be provided with lattice bars and shall have tie-plates as near each end as practicable. Tie plates shall be provided at intermediate points where the lattice is interrupted. In main members the end tie plates shall have a length not less than the distance between the lines of rivets connecting them to the flanges, and intermediate ones not less than one-half this distance. Their thickness shall be not less than one-fiftieth of the same distance.

267. **Lattice Bars.** The minimum width of lattice bars and the size of the connecting rivets shall be as follows:

15 inch channels or built up sections with angles over three (3) inches, width  $2\frac{1}{2}$  inches; rivets  $\frac{7}{8}$  inch.  
12 and 10 inch channels or built up sections with angles over three (3) inches, width  $2\frac{1}{2}$  inches; rivets  $\frac{3}{4}$  inch.

8 and 9 inch channels, width 2 inches; rivets  $\frac{5}{8}$  inch.

6 and 7 inch channels, width  $1\frac{3}{4}$  inches; rivets  $\frac{5}{8}$  inch.

Single lattice bars shall have a thickness not less than 1-40 or double lattice bars connected by a rivet at the intersection, not less than 1-60 of the distance between the rivets connecting them to the members. They shall be inclined at an angle not less than 60 degrees with the axis of the member for single latticing, nor less than 45 degrees for double latticing with riveted intersections.

268. Lattice bars shall be so spaced that the portion of the flange included between their connections shall be as strong as the member as a whole.

269. **Abutting Joints.** In continuous compression members, abutting joints shall be placed as close to the panel points as practicable. Abutting joints with milled faces shall be provided with a splice plate on each side of the web or plate spliced, and shall have at least two rows of closely pitched rivets on each side of the joint.

270. Compression members having abutting joints with untooled faces and all riveted tension members must be fully spliced. Adjacent ends must, however, be dressed straight and true, so there will be no open joints.

271. **Pin Plates.** Pin-holes shall be reinforced by plates where necessary, and at least one plate shall be as wide as the flange will allow and be on the same side as the flanges or angles. They shall contain sufficient rivets to distribute their portion of the pin pressure to the full cross-section of the member. At least one of these plates shall extend not less than 6 inches beyond the near edge of the tie plate.

272. **Pins.** Pins shall be long enough to insure a full bearing of all the parts connected upon the turned body of the pin. They shall be secured by chambered nuts. The screw shall be long enough to admit of burring the threads.

273. **Filling Rings.** Members packed on pins shall in all cases be held against lateral movement by means of ring fillers.

274. **Bolts.** Wherever bolts are used in place of rivets, the holes shall be reamed parallel and the bolts turned to a driving fit.

275. Where members are connected by bolts, the turned unthreaded shank shall be long enough to extend through the plates connected. A washer at least  $\frac{1}{4}$  inch thick shall be used under the nut. Bolts shall not be used in place of rivets except by special permission. Heads and nuts shall be hexagonal.

276. **Indirect Splices.** Where splice plates are not in direct contact with the parts which they connect, as in case fillers are used, rivets shall be used in excess of the number theoretically required to the extent of one-third of the number for each intervening plate.

277. **Friction Rollers.** All bridges having spans of more than 80 feet, shall have hinged bolsters on both ends, and at one end nests of turned friction rollers running between planed surfaces provided with guide bars. These rollers shall be not less than  $2\frac{7}{8}$  inches in diameter for spans of 100 feet or less. For greater spans this diameter shall be increased in the proportion of 1 inch for each 100 feet of additional span length.

278. **Pedestals and Bed Plates.** Pedestals shall be made of riveted plates and angles. All bearing surfaces of the base plates and vertical webs shall be planed. The vertical webs shall be secured to the base by angles two (2) rows of rivets in the vertical legs. No base plate or web connection angle shall have a thickness of less than  $\frac{1}{2}$  inch. The vertical webs shall be of sufficient height and contain sufficient material and rivets to distribute the loads over the bearings or rollers.

279. Where the size of the pedestal permits, the vertical webs shall be rigidly connected transversely.

280. All the bed plates and bearings under fixed and movable ends shall be fox-bolted to the masonry; for trusses, these bolts shall be not less than  $1\frac{1}{8}$  inches in diameter, and 18 inches long; for plate and other girders, not less than  $\frac{7}{8}$  inch in diameter and 18 inches long. The contractor shall furnish all bolts, drill all holes and set bolts to place with sulphur or Portland cement.

281. While the expansion ends of all trusses must be free to move longitudinally under changes of temperature, they shall be anchored against lifting or moving sideways.

282. Allowance shall be made for a change of length of bridge, due to a variation of temperature of 75 degrees either way from the normal.

## FLOOR SYSTEM.

283. **Floor Beams.** Floor beams shall be riveted directly to the trusses and shall be faced true and square, and to correct lengths. Allowance shall be made in the thickness of the end angles to provide for such facing without reducing the required effective strength of the angles.

284. **End Spacers for Stringers.** Where end floor beams cannot be used, stringers resting on masonry shall have channel spacers near their ends.

285. Such spacers shall be rigidly bolted to the masonry at the fixed end of the bridge and the stringers shall be rigidly bolted to the spacer. At the free end the spacer shall be rigidly bolted to the masonry and slotted holes shall be provided either in the stringers or the spacer and the stringers bolted in such manner as to allow free longitudinal but no lateral movement. The slotted holes shall be long enough to provide for a change of length of bridge due to a variation of temperature of 75 degrees either way from the normal.

## BRACING.

286. **Rigid Bracing.** Lateral, longitudinal and transverse bracing in all structures shall be composed of rigid members with riveted connections and shall be securely riveted at their intersections to prevent sagging and rattling.

287. **Portals.** Through truss spans shall have riveted portal braces rigidly connected to the end posts and top chords. They shall be as deep as the clearance will allow.

288. **Transverse Bracing.** Intermediate transverse frames shall be used at each panel of through spans having vertical truss members where the clearance will permit. Transverse frames shall be capable of transferring at least 0.7 of the wind load from the top to the bottom chord.

289. The top and bottom lateral systems shall, however, be designed to carry the entire wind load to the shoes in the usual manner.

## TRUSSES.

290. **Camber.** Truss spans shall be given a camber by making the panel length of the top chords, or their horizontal projections, longer than the corresponding panels of the bottom chord in the proportion of  $\frac{1}{8}$  inch to 10 feet.

291. **Rigid Members.** Hip verticals and similar members, and preferably the two end panels of the bottom chords of pin-connected trusses up to 300 foot spans, shall be rigid.

292. **Eye-Bars.** Eye-bars shall be straight and true to size, and shall be free from twists, folds in the neck or head, or any other defect. Heads shall be made by up-setting, rolling or forging. Welding will not be allowed. The form of heads will be determined by the dies in use at the works where the eye-bars are made, if satisfactory to the engineer, but the manufacturer shall guarantee the bars to break in the body when tested to rupture. The thickness of the head and neck shall vary not more than 1-16 inch from that specified.

# Materials

## GENERAL PROPERTIES OF STEEL.

293. **Process of Manufacture.** Steel shall be made by the open-hearth process.

294. **Allowable Percentage of Phosphorus.** The phosphorus shall not exceed 0.06 of one per cent for steel made by the acid method, or 0.04 for steel made by the basic method.

295. **Finish.** The steel shall be uniform in character for each specified kind. The finished bars, plates and shapes shall be free from cracks on the face or corners, and have a clean, smooth finish. No work shall be put upon any steel at or near the blue temperature or between that of boiling water and of ignition of hard wood sawdust.

296. **Tensile Strength.** The tensile strength, elastic limit and ductility shall be determined by samples cut from the finished material after rolling. The sample shall be cut at least 12 inches long, and have a uniform sectional area not less than  $\frac{1}{4}$  square inch. The elastic limit, as indicated by the drop of the beam, shall be recorded in the test reports.

297. **Condition of Specimens.** Material which is to be used without annealing or further treatment shall be tested in the condition in which it comes from the rolls. When material is to be annealed or otherwise treated before use, the specimen representing such material shall be similarly treated before testing for tensile strength.

298. **Elongation.** The elongation shall be measured on an original length of 8 inches. Two test pieces shall be taken from each melt of finished material, one for tension and one for bending.

299. **Kind of Failure.** All samples or full sized pieces shall show a uniformly fine grained fracture of a blue steel-gray color, entirely free from fiery lustre or blackish cast.

## MEDIUM STEEL.

300. **Ultimate Strength.** Medium steel shall have an ultimate strength, when tested in samples of the dimensions above stated, of 60,000 to 68,000 pounds per square inch, an elastic limit of not less than one-half of the ultimate strength and a minimum elongation of 22 per cent in 8 inches. Steel for pins may have a minimum elongation of 15 per cent.

301. **Bending Test.** Before or after heating to a low cherry red and cooling in water at 82 degrees Fahrenheit, this steel shall stand bending to a curve whose inner radius is one and a half times the thickness of the sample, without cracking.

302. **Drifting Test.** For all medium steel  $\frac{3}{8}$  inch or less in thickness, rivet holes, punched as in ordinary practice, shall stand drifting to a diameter of one-third greater than the original holes without cracking either in the periphery of the holes or on the external edges of the pieces whether they may be sheared or rolled.

## RIVET STEEL.

303. **Ultimate Strength.** Rivet steel shall have an ultimate strength of 50,000 to 58,000 pounds per square inch, an elastic limit not less than one-half the ultimate strength and elongation of 26 per cent.

304. **Bending Test.** The steel for rivets shall, under a bending test, stand closing solidly together without sign of fracture.

305. **Eye Bars.** Eye bar material,  $1\frac{1}{2}$  inches and less in thickness, shall, on test pieces cut from finished material, fill the above requirements for medium steel. For thicknesses greater than  $1\frac{1}{2}$  inches, there will be allowed a reduction in the per centage of elongation of 1 per cent for each  $\frac{1}{8}$  inch of additional thickness, to a minimum of 20 per cent.

306. **Pins.** Pins over 7 inches in diameter shall be forged. Blooms for pins shall have at least three (3) times the sectional area of the finished pins.

307. **Allowable Variation.** A variation of cross-section or weight in the finished members of  $2\frac{1}{2}$  per cent from the specified size may be cause for rejection.

## STEEL CASTINGS.

308. Steel castings shall be true to form and dimensions, have a workmanlike finish and be free from injurious blowholes and defects. All castings must be annealed.

309. **Tests.** When tested in specimens of uniform sectional area of at least  $\frac{1}{2}$  square inch for a distance of 2 inches, they shall show an ultimate strength of not less than 67,000 pounds per square inch, an elastic limit of one-half the ultimate, and an elongation in 2 inches of not less than 10 per cent.

310. **Character of Metal.** The metal shall be uniform in character, free from hard or soft spots, and be capable of being properly tool finished.

## CAST IRON.

311. **Cast Iron.** Except where cast steel or chilled iron is required, all castings shall be of tough, gray iron, free from cold shuts or injurious blow holes, true to form and thickness, and have a workmanlike finish. Sample pieces, 1 inch square, cast from the same heat of metal in sand moulds, shall be capable of sustaining, on a clear span of 12 inches, a central load of 2,500 pounds when tested in a rough bar. A blow from a hammer shall produce an indentation on a rectangular edge of the casting without flaking the metal.

312. **Forgings and Shafting.** The material used for forgings shall be of "medium" basic or acid "open hearth" steel, and have a good finish and uniform quality. The phosphorous content shall not exceed 0.06 of one per cent. When tested in specimens of not less than  $\frac{1}{2}$  inch in diameter, it shall show an ultimate strength of at least 60,000 pounds per square inch with an elastic limit of at least 50 per cent of the ultimate, and an elongation of at least 28 per cent in 2 inches, and a test specimen 1 inch by  $\frac{1}{2}$  inch shall bend cold 180 degrees over a diameter equal to its thickness without a sign of fracture. All steel forgings must be properly annealed.

## TIMBER.

313. Timber when called for, unless otherwise specified, shall be strictly first class spruce, white pine, Douglas fir, Southern long leaf yellow pine or white oak bridge timber, sawed true and straight grained, free from wind shakes, large or loose knots, decayed or sap wood, worm holes, or other defects impairing its strength or durability, and shall be subject to the inspection and acceptance of the Engineer.

## Workmanship

314. **General.** All parts forming a structure shall be built in accordance with the approved working drawings. The workmanship and finish shall be equal to the best practice in modern bridge shops.

315. **Straightening Material.** Material shall be thoroughly straightened in the shop before being laid off or worked in any way.

316. **Finish.** Shearing shall be neatly and accurately done and all portions of the work exposed to view neatly finished.

317. **Size of Rivets.** The size of rivets, called for on the plans, shall be understood to mean the actual size of the cold rivet before heating.

318. **Rivet Holes.** When general reaming is not required the diameter of the punch shall be not more than 1-16 inch greater than the diameter of the rivet; nor the diameter of the die more than  $\frac{1}{8}$  inch greater than the diameter of the punch. Material more than  $\frac{3}{4}$  inch thick shall be sub-punched and reamed or drilled from the solid.

319. **Punching.** All punching shall be accurately done. Drifting to enlarge unfair holes will not be allowed. If the holes must be enlarged to admit the rivet, they shall be reamed. Poor matching of holes will be considered sufficient cause for rejection.

320. **Sub-Punching and Reaming.** Where reaming is required, the diameter of the punch used shall be at least 3-16 inch smaller than the nominal diameter of the rivet. Holes shall then be reamed to a diameter of not more than 1-16 inch larger than the nominal diameter of the rivet. All reaming shall be done with twist drills.

321. **Reaming After Assembling.** When reaming is required, it shall be done after the pieces forming one member are assembled and firmly bolted together. If necessary to take the pieces apart for shipping and handling, the respective pieces reamed together shall be so marked that they may be assembled in the same position in the final setting up. No interchange of reamed parts will be allowed.

322. **Edge Planing.** Sheared edges or ends, shall, when required, be planed at least  $\frac{1}{8}$  inch.

323. **Burrs.** The outside burrs on reamed holes shall be removed.

324. **Assembling.** Riveted members shall have all parts well pinned up and firmly drawn together with bolts, before riveting is commenced. Contact surfaces shall be heavily coated with the paint herein specified before riveting.

325. **Lattice Bars.** Lattice bars shall have neatly rounded ends.

326. **Web Stiffeners.** Stiffeners shall fit neatly between flanges of girders. Where tight fits are called for, the ends of the stiffeners shall be faced and shall be brought to a true contact bearing with the flange angles.

327. **Splice Plates and Fillers.** Web splice plates and fillers under stiffeners shall be cut to fit within  $\frac{1}{8}$  inch of the flange angles.

328. **Web Plates.** Web plates of girders, which have no cover plates, shall be flush with the backs of angles or project above the same not more than  $\frac{1}{8}$  inch, unless otherwise called for. When web plates are spliced, not more than  $\frac{1}{4}$  inch clearance between ends of plates will be allowed.

329. **Connection Angles.** Connection angles for floor beams and stringers shall be flush with each other and correct as to position and length of girder.

330. **Rivets.** Rivets shall be driven by pressure tools wherever possible. Pneumatic hammers shall be used in preference to hand driving.

331. **Riveting.** Rivets shall have a neat and finished appearance with heads of approved shape, full and of equal size. They shall be central on the shank and shall grip the assembled pieces firmly. Recupping and calking will not be allowed. Loose, burned or otherwise defective rivets shall be cut out and replaced. In cutting out rivets, great care shall be taken not to injure the adjacent metal. If necessary they shall be drilled out.

332. **Members to be Straight.** The several pieces forming one member shall be straight and fit closely together, and the finished member shall be free from twists, bends, or open joints.

333. **Finish of Joints.** Abutting joints shall be cut or dressed true and straight and fitted closely together, especially where open to view. In compression joints, depending on contact bearing, the surfaces shall be truly faced, so as to have even bearing after they are riveted up complete and when perfectly aligned.

334. **Eye-Bars.** The eye-bars composing a member shall be so arranged that the surfaces of adjacent bars shall not come in contact; they shall be as nearly parallel to the axis of the truss as possible, the maximum inclination of any bar being limited to one inch in 16 feet.

335. **Boring Eye-Bars.** Before boring, each eye-bar shall be properly annealed and carefully straightened. Pin-holes shall be in the center line of bars and in the center of heads. Bars of the same length shall be bored so accurately that, when placed together, pins 1-32 inch smaller in diameter than the pin holes can be passed through the holes at both ends of the bars at the same time without forcing.

336. **Pin Holes.** Pin-holes shall be bored true to gauge, smooth and straight; at right angles to the axis of the member and parallel to each other, unless otherwise called for. The boring shall be done after the member is riveted up.

337. **Variation in Pin Holes.** The distance center to center of pin holes shall be correct to within 1-32 inch, and the diameter of the holes shall be not more than 1-50 inch larger than that of the pin, for pins up to 5 inches in diameter, and 1-32 inch for larger pins.

338. **Pins and Rollers.** Pins and rollers shall be accurately turned to gauge, shall be straight, smooth and entirely free from flaws.

339. **Screw Threads.** Screw threads shall make tight fits in the nuts and shall be U. S. standard, except above the diameter of  $1\frac{3}{8}$  inches, when they shall be made with six threads per inch.

340. **Upset Ends.** All bars with screw ends shall be upset, so that the diameter at the bottom of the threads shall be 1-16 inch larger than any part of the body of the bar. Where closed sleeve nuts are used on adjustable members, the effective length of thread shall be legibly stamped at the screw end of each bar. Adjustable counters are to be avoided where practicable.

341. **Annealing.** Steel, except in minor details, which has been partially heated, shall be properly annealed.

342. **Steel Castings.** All steel castings shall be annealed.

343. **Welds.** Welds in steel will not be allowed.

344. **Bed Plates.** Expansion bed plates shall be planed true and smooth. Cast wall plates shall be planed top and bottom. The cut of the planing tool shall correspond with the direction of expansion.

345. **Pilot Nuts.** Pilot and driving nuts shall be furnished for each size of pin.

## INSPECTION.

346. **Facilities.** All facilities for inspection of the materials and workmanship shall be furnished by the contractor.

347. **Test Pieces.** He shall furnish without charge such prepared specimens of the several kinds of steel to be used, as may be required to determine their character.

348. **Testing Machine.** The contractor shall furnish, free of cost, the use of a testing machine capable of testing the above specimens at all mills where the steel is manufactured.

349. **Tests of Large Pieces.** Full sized parts of the structure may be tested at the option of the engineer, but if tested to destruction, such material shall be paid for at cost, less its scrap value to the contractor, if it proves satisfactory. If it does not stand the specified tests, it will be considered rejected material, and be solely at the cost of the contractor.

350. **Fabrication.** The contractor shall notify the engineer from time to time of the progress of fabrication and furnish every facility necessary for the engineer to inspect the work in the fabricating shop. It is understood, however, that the engineer may waive shop inspection and make complete inspection of all fabricated work when the same is delivered at the site of the bridge. Whether or not shop inspection is made, fabricated steel may be rejected at any time prior to final acceptance of the bridge provided it does not conform to the specifications.

## FINAL TEST.

351. **Final Test.** Before final acceptance, the engineer may make a thorough test by passing over the structure the specified loads, or their equivalent, or by resting the maximum load upon the structure for twelve (12) hours.

After each test the structure shall return to its original position without showing any permanent deformation.

# SPECIFICATIONS FOR PAINTING

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## GENERAL.

352. **Shop Painting Under Cover.** All steel shall be received and painted under cover. No painting, either at the shops or in the field, shall be done in wet or freezing weather.

353. **Three Coats to Be Used.** The shop coat of paint shall consist of pure sublimed white lead and pure boiled linseed oil; the second coat, which shall be applied in the field, shall consist of pure boiled linseed oil and pure sublimed blue lead; the third coat shall consist of pure boiled linseed oil and sublimed blue lead, tinted as directed by the engineer.

## SAMPLES.

354. **Preliminary Sample.** Before ordering the paint, a sample of at least 2 pounds shall be furnished the engineer, which sample will be tested in the laboratory of the Illinois Highway Department. The paint shall be well mixed before the sample is selected, and care shall be taken to obtain a good representative sample. The sample, if approved, will be used in determining the merits of the paint furnished on the work. All paint used shall equal the sample in quality.

355. **Final Sample.** Samples of paint delivered at the shop and in the field shall be furnished the inspector by the contractor, said samples to be selected by the inspector and tested in the laboratory of the Illinois Highway Department before any paint is applied. The contractor shall, therefore, secure the necessary paint in ample time so that no delay will be caused by the time necessarily used in testing, for which 10 days shall be allowed from the time the sample is received at the laboratory.

## ANALYSIS.

356. **Moisture.** The paint shall in no case contain moisture to exceed one per cent, nor shall it be soluble in water to the extent of more than one per cent.

357. **Quantity of Pigment.** The mixed paint shall contain at least 55 per cent of pigment by weight. Should the paint be in paste form, enough paste shall be added to boiled linseed oil to give at least 55 per cent of pigment by weight to the mixed paint. This requires usually at least 18 pounds of paste per gallon of linseed oil.

358. **Determination of Percent of Pigment.** The determination of the amount of pigment will be made as follows:

359. The samples will be weighed and, when possible, the clear vehicle drawn off and tested to determine its conformity with the specifications.

360. The remaining vehicle will then be extracted four (4) times with 88 degrees gasoline, and washed once with benzole and once with ether. When the vehicle cannot be drawn off, one-half of the sample will be extracted by centrifuging the paint, and after the vehicle is removed, washing the pigment with gasoline, benzole and ether. One hundred (100) minus the per cent of pigment found, will be considered as the per cent of vehicle.

361. **Linseed Oil.** When in paste form, the paint shall be mixed with pure boiled linseed oil. Such oil as well as the vehicle obtained from mixed paint will be subjected to standard tests for the purity of the boiled linseed oil. It shall have a specific gravity at 15.5 degrees C of not less than .935 nor more than .945. It shall contain no mineral oils, benzine rosin, rosin oil, maize or corn oil, fish oil, cottonseed oil, rape oil, soya bean oil, or saponified or unsaponified oil other than linseed oil. A small amount of turpentine may be added as a drier only on the approval of the engineer. The film obtained after flowing the oil over glass and allowing it to drain in a vertical position must be dry to the touch after 24 hours at 21 degrees C.

## APPLICATION.

362. **Applying the Shop Coat.** All metal work, including railings and stringers, shall be cleaned from all rust, scale, dirt or grease, and shall be thoroughly dry before the first coat of paint is applied. If rust, which, in the opinion of the inspector, cannot be removed, is found on any piece, that piece shall be rejected. All parts which come in contact shall be painted two coats before they are riveted together. Round brushes shall be used. Pieces and parts which are not accessible for painting after erection, including tops of stringers, eye-bar heads, ends of posts, chords, etc., shall have two coats of paint before leaving the shop. While metal work is being erected in place, all abrasions of the original paint and all rivet and bolt heads and location marks must be cleaned and painted, preparatory to the second coat.

363. **Applying Field Coats.** After the structure is complete in place, touched up as described above, and cleaned from all rust, scale, dirt, grease and oil that may have accumulated during erection, two coats of sublimed blue lead paint shall be applied and well brushed out, each coat to be applied only after the previous coat has become thoroughly dry, allowing at least one week for this purpose. The last coat shall be tinted as required by the engineer.

364. **Machined Surfaces.** Machined surfaces shall be coated with white lead and tallow before shipment or before being placed in the open.

### **PAINTING OLD BRIDGES.**

365. **Clearing.** When the contract requires the painting of an old steel bridge, all steel work in the structure shall, by means of the sand blast or with scrapers, wire brushes and the painter's torch, be cleaned from all loose paint, scale, rust, dirt and other foreign material, with the utmost care.

366. In any case, the character of the cleaning shall be equal to that produced by the sand blast.

367. Not more than 5 hours shall intervene between the cleaning and the application of the first coat of paint.

368. **Samples.** Samples of paint shall be submitted and tested as hereinbefore provided.

369. **Painting.** Immediately before the application of the first coat, the steel shall be thoroughly dusted with a soft brush or a clean cloth.

370. Two coats of sublimed blue lead paint of the quality herein specified shall be used and applied as hereinbefore specified.



# SPECIFICATIONS FOR CREOSOTED TIMBER FLOORS

## Plank Floors and Sub-Planking

### MATERIALS.

371. **Quality of Material.** The timber used for creosoted plank floors, sub-planking, nailing pieces, shims, retaining pieces, scupper blocks, hub-guard and all other dimension lumber except paving blocks, shall be strictly first class red oak, spruce, Douglas fir, long leaf or short leaf pine, and shall be cut from green standing timber and thoroughly seasoned before treatment. It shall be straight grained, free from shakes, large or loose knots, decayed wood, worm holes or any other defects that would impair its strength or durability.

372. **Dimensions.** The materials shall be sawed straight and true and shall not vary in thickness from that called for on the plans by more than 1-16 inch either way for sub-planking and 3-16 inch for plank floors.

373. Lumber for plank floors and sub-planking shall be from 8 inches to 12 inches wide and of the length and thickness called for on the plans.

374. All lumber shall be cut to the width and thickness called for before treatment.

375. **Impregnation.** All lumber shall be impregnated with at least twelve (12) pounds of creosote oil per cubic foot of material. The oil shall be of the kind and quality herein specified for dimension timber.

376. **Defective Material.** All plank or other timber showing defects, shall be removed immediately from the site of the work. Any piece of timber noticeably deficient in creosote shall be rejected in the same manner.

### PLACING.

377. **Nailing Pieces.** The nailing pieces shown on the plans shall be rigidly bolted to the channels or I beams by means of  $\frac{5}{8}$  inch bolts spaced not more than three feet apart. Nailing pieces bolted to the side of beams or channels shall have the top of the nailing piece flush with the top of the beam or channel.

378. **Creosoted Plank Floor.** All plank for creosoted plank floors having no special wearing surface shall be laid with close joints and fastened to the nailing pieces with two wire spikes at each intersection. Such spikes shall have a length equal, at least, to double the thickness of the plank.

379. **Sub-Planking.** The sub-planking for creosoted block floors or for floors to be covered with a bituminous wearing surface, shall be laid with tight joints and shall, unless otherwise shown on the plans, be fastened to the outside nailing pieces by means of two 6 inch lag screws, at each end of each plank, and to the intermediate nailing pieces by means of two wire spikes having a length at least equal to double the thickness of the plank. Wood shims when called for on the plans shall be rigidly spiked to the sub-planking.

380. Holes for the lag screws shall be bored slightly smaller in diameter than the shank of the same and have a depth of  $1\frac{1}{2}$  inches less than the length of the screw below the head.

381. **Retaining Pieces.** Retaining pieces for block floors shall be fastened by means of bolts, as shown on the plans. For floors having a bituminous wearing surface, they shall be spiked to the sub-planking by means of spikes having a length equal to three times the thickness of the retaining piece.

382. **Scupper Blocks.** Scupper blocks shall be rigidly fastened to the retaining piece by means of wire spikes.

383. **Hub Guards.** Felloe guards shall be placed on top of the scupper blocks and fastened in place by means of one  $\frac{5}{8}$  inch bolt at each scupper block. The bolts shall extend entirely through the hub guard, scupper block, retaining piece, sub-plank and nailing piece.

384. **Washers.** Wherever the head or nut of a bolt or lag screw would otherwise come in contact with the timber, a standard size washer shall be used underneath the head or nut.

385. All vertical bolts shall have the nut at the lower end.

386. **Countersinking.** Countersinking shall be resorted to whenever the heads of screws or bolts would otherwise interfere with assembling the work. Recesses formed by countersinking shall be filled with hot asphalt.

# Bituminous Wearing Surface

## GENERAL.

387. Where called for on the plans, bituminous wearing surface shall be constructed in the following manner:

## CONSTRUCTION.

388. **Calking.** After the sub-planking and retaining pieces have been laid, all joints shall be calked with oakum by forcing it into the cracks with a proper calking tool in such manner as to form a water-tight joint, leaving the surface of the calking not less than  $\frac{3}{8}$  inch nor more than  $\frac{3}{4}$  inch below the surface of the sub-planking.

389. The sub-planking shall then be thoroughly cleaned from all foreign material and the cracks shall be filled and the plank covered to a depth of approximately  $\frac{1}{8}$  inch with asphalt of the character herein specified, which shall be applied at a temperature of not less than 400 degrees Fahrenheit. The sub-planking shall be dry when the asphalt is applied.

390. **Aggregate.** The aggregate shall consist of screened gravel, which shall have been approved by the engineer, dry, free from dust, and graded in size from  $\frac{3}{8}$  inch to  $\frac{3}{4}$  inch.

391. **Placing.** This gravel shall be spread on the asphalt covering, while the same is hot, and in a quantity which will just cover the asphalt. The thickness must not exceed that which will be formed by a single layer of the gravel pebbles.

392. Upon the material thus spread, there shall be poured hot asphalt until the interstices are all filled, the asphalt being at a temperature of not less than 400 degrees Fahrenheit.

393. Upon the layer of asphalt thus poured there shall be spread a second layer of gravel which shall not exceed the thickness of a single layer of pebbles, but which must be spread in sufficient quantity to cover completely the layer of asphalt.

394. Upon the layer of gravel thus spread there shall be poured hot asphalt until all the interstices are filled, the asphalt having a temperature of not less than 400 degrees Fahrenheit.

395. **Finish.** The surface shall then be covered with a layer of pebbles just sufficient to cover the asphalt, the pebbles to be well rolled or tamped into the asphalt and the surface finally covered with coarse sand sufficient to take up any free asphalt. After the surface has stood for one day, it may be opened to traffic.

# Creosoted Wood Block Paving

## GENERAL.

396. Wood block pavement shall have the thickness shown on the plans, and shall be constructed of the materials and in the manner herein specified.

397. **Quality.** The wood from which the blocks are made shall be sound, long leaf yellow pine, or Oregon fir, shall be well manufactured, saw-buttled, free from large, coarse or loose knots, worm holes, knot holes and free from the following defects: shakes, wane, checks, bark, incipient or other decay.

398. All blocks used, however, must be of the same kind of material.

399. Each block shall show an average of at least eight (8) annual growth rings per inch.

400. **Dimensions.** The paving blocks cut from lumber or wood above specified shall be well manufactured, truly rectangular and of a uniform size. They shall be surfaced on one side and one edge; and the top and bottom shall be evenly sawn. The blocks shall not vary in width or thickness more than 1-16 inch. The length shall be not less than 6 inches nor more than 10 inches; the width shall be not less than 3 inches nor more than 4 inches, but all blocks used shall be of the same width.

401. **Impregnation.** All blocks shall be impregnated with at least 16 pounds of creosote oil per cubic foot of material. The oil shall be of the kind and quality herein specified for wood blocks.

402. **Defective Blocks.** All blocks cut from defective material, split, checked and badly warped blocks and blocks not cut true to dimensions shall be thrown out and removed immediately from the site of the work. All blocks noticeably deficient in creosote shall be rejected, and if the number of such deficient blocks should be as great as 20 per cent of the total quantity to be used, the entire lot will be rejected.

## PLACING.

403. **Laying Felt Cushion and Paving Blocks.** After the sub-planking and retaining pieces have been laid, the sub-planking shall be covered with a thin layer of asphalt of the kind herein specified. Immediately after the asphalt has been spread, it shall be covered with a layer of 4-ply bituminous felt thoroughly rolled to contract with the asphalt. The layer of felt so placed shall then be coated with a thin layer of asphalt of the quality herein specified, and the creosoted blocks immediately laid thereon before the asphalt has had time to cool.

404. The creosoted blocks shall be laid in regular courses at right angles to the center line of the roadway. The blocks shall be laid with  $\frac{1}{8}$  inch joints and shall be so laid that the blocks in adjacent rows will break joints by at least 3 inches. Immediately after the blocks have been laid, they shall be rolled or tamped until firmly bedded on the asphalt cushion.

405. **Expansion Joints.** An expansion joint  $\frac{1}{2}$  inch wide shall be provided along each retaining piece and shall be kept free from obstruction during construction by means of a strip of wood  $\frac{1}{2}$  inch thick extending entirely down to the felt cushion.

406. After the wood block pavement has been laid and rolled or tamped, the wooden strips shall be removed from the expansion joints, which shall then be filled with asphalt or coal tar pitch filler as herein specified.

407. **Filling Joints.** The entire surface of the roadway shall, after the blocks have been laid, be gone over with a paint coat of the asphalt or pitch filler herein specified, which shall be applied at a temperature not less than 400 degrees F. for the asphalt filler nor less than 300 degrees F. for the pitch filler, and shall be applied in such quantity as will completely fill all joints between blocks. After the filler has been applied, the entire surface shall be covered with a light coating of clean, coarse sand or granite chips of a size that will pass through a  $\frac{1}{4}$  inch screen.

## Creosote Oil and the Treatment of Timber

### CREOSOTE OIL.

408. **General Character.** The oil shall be a pure coal tar product, free from any adulterations. It shall not contain any petroleum oil or any product obtained from petroleum, and shall contain not more than 3 per cent of matter insoluble in benzole and chloroform. No oil obtained wholly or in part from water gas tar, or oil will be accepted.

409. **Distilling Test.** The apparatus for distilling the creosote shall consist of a stoppered glass retort having a capacity, as nearly as can be obtained, of 8 ounces up to the bend of the neck, when the bottom of the retort and the mouth of the off-take are in the same plane. The bulb of the thermometer shall be placed  $\frac{1}{2}$  inch above the liquid in the retort at the beginning of the distillation, and this position must be maintained throughout the operation. The condensing tube shall be attached to the retort by a tight cork joint. The distance between the thermometer and the end of the condensing tube shall be 22 inches, and during the process of distillation, the tube may be heated to prevent the congealing of the distillates. The bulb of the retort and at least 2 inches of the neck shall be covered with a shield of heavy asbestos paper during the entire process of distillation, so as to prevent heat radiation, and between the bottom of the retort and the flame of the lamp or burner 2 sheets of wire gauze, each 20 mesh fine and at least 6 inches square shall be placed. The flame shall be protected against air currents.

410. The distillation shall be continuous and uniform, the heat being applied gradually. It shall be at a rate approximating 1 drop per second; 100 grams of the oil shall be taken for distillation and all percentages determined by weight in comparison with dry oil.

411. **Oil for Dimension Timber.** The specific gravity of the oil shall be not less than 1.03 nor more than 1.08 at 25 degrees Centigrade, and when subjected to a distilling test in the manner hereinbefore described, the amount of the distillate shall not exceed the following:

Up to 200° Centigrade, 2 per cent.

Up to 235° Centigrade, 35 per cent.

Residue at 355° Centigrade, not more than 35 per cent.

412. **Oil for Paving Blocks.** The specific gravity of the oil shall be at least 1.10 and not more than 1.13 at 25 degrees Centigrade, and when subjected to a distilling test in the manner herein described, the amount of the distillate shall not exceed the following:

Up to 150° Centigrade, 2 per cent.

Up to 210° Centigrade, 10 per cent.

Up to 235° Centigrade, 20 per cent.

Up to 315° Centigrade, 40 per cent.

## TREATMENT OF TIMBER.

413. **Impregnation.** The timber shall be placed in an air-tight cylinder where, by means of steam, at a pressure not to exceed 30 pounds per square inch, and the vacuum pump, the sap in the timber will be vaporized and the moisture removed. When the timber is thoroughly dry, the cylinder shall be filled with oil and pressure shall then be applied and increased gradually to not more than 300 pounds per square inch, and maintained until the required amount of oil has been forced into, and retained, in the timber and until the oil has impregnated the timber to the satisfaction of the engineer. In the process of treating the timber, a correction shall be made for any water contained in the cylinder. Compensation shall also be made for leaks and other wastes of oil that may occur during treatment.

414. **Equipment.** The oil tanks and cylinders in which the timber is treated shall be equipped with all necessary gauges, thermometers and draw cocks, in order to facilitate a thorough inspection of the materials and treatments. The plant shall be provided with proper means of obtaining the absolute measurement and weight of all oils entering the cylinder and the amount of oil absorbed by the timber.

415. **Notification of Treatment.** The creosoting company shall notify the state highway engineer, Springfield, Illinois, a sufficient length of time in advance of the date the timber for this contract will be creosoted, so that an inspector may be sent from Springfield, Illinois, to the creosoting plant and arrive in time to inspect the material and check the treatment at the plant.

## PLANT INSPECTION OF BLOCKS.

416. **Determining Quantity of Oil in Blocks.** When plant inspection is made by the engineer, the quantity of creosote contained in blocks shall be determined as follows: The trucks containing the blocks shall be weighed immediately before being placed in the cylinder for treatment, and shall again be weighed after treatment, and the difference in weight shall be taken as the quantity of creosote impregnated in the blocks.

417. **Oil Samples.** The quality of the creosote shall be determined from samples furnished the inspector before treatment and may be confirmed by a sample taken from the cylinder during, or immediately after, treatment.

## FIELD INSPECTION OF BLOCKS.

418. **Plant Inspection May be Waived.** Should the State Highway Engineer notify the creosoting company that plant inspection will be waived on creosoted blocks, then the amount of oil contained therein shall be determined by extraction from blocks selected by the inspector.

419. **Block Samples.** Ten blocks of the greatest length furnished will be taken for each 700 square yards of roadway to be paved, but in no case will less than 10 blocks be selected.

420. Three  $\frac{3}{4}$  inch holes will be bored through each block at right angles to the face of the same presenting the greatest superficial area parallel to the fibers of the wood. One hole will be bored through the middle of the block and the other two near diagonally opposite corners and at a distance of  $\frac{3}{4}$  inch from the adjacent edges of the block.

421. **Quality of Oil.** In case plant inspection is waived, no determination of the quality of creosote will be made, but the creosoting company will be required to furnish a certified statement, signed by proper officers of the company, which statement shall indicate the results of analysis of the oil, which analysis shall be made in accordance with the methods heretofore described in these specifications.

422. **Extraction Test Moisture.** The moisture will be determined by the Standard U. S. Forest Service method, as outlined in circular No. 134 of the Forest Service.

423. **Extract.** About 30 grams of the thoroughly mixed creosote chips will be placed in a Soxhlet extraction apparatus and extracted with chloroform until the latter on passing through the chips is no longer discolored. The chips will then be dried at 110 degrees C until of constant weight; all of the moisture being evaporated at this temperature. The difference in weight of the chips before and after extraction will be taken as the weight of water, creosote, rosin and turpentine, contained in the chips.

424. **Rosin.** The chloroform extract will then be distilled down to about one hundred CC and saponified with 5 per cent sodium carbonate ( $\text{Na}_2\text{CO}_3$ ) solution. The aqueous solution of sodium resinate will be acidified, the rosin dissolved out with ether and the ether distilled off. The residue will be resaponified with a 5 per cent. solution of sodium acid carbonate ( $\text{NaHCO}_3$ ), the aqueous liquid acidified and the rosin dissolved with ether. The ethereal rosin solution will then be transferred to a tarred glass crystallizing dish and evaporated and dried at 110 degrees C.

425. **Turpentine.** The turpentine will be calculated from the amount of rosin found.

426. **Creosote.** The creosote will be determined by subtracting the percentages of moisture, rosin and turpentine from the per cent of total extract and a correction added for the amount of free carbon found in the analysis of the oil.

427. **Specific Gravity.** The calculations will be based on the specific gravity of the material obtained, whenever possible, by weighing and measuring the samples selected before the borings are made.

428. Should it be impracticable to obtain the specific gravity in this way, the specific gravity of the chips will be determined and used.

429. **Requirements of Tests.** Should the amount of oil found by the above described test be less than that called for in the specifications, the material will be rejected.

## INSPECTION OF DIMENSION TIMBER.

430. **Tests of Dimension Timber.** When plant inspection is made on dimension timber, the determination of quality and quantity of creosote shall be made as described herein for creosoted blocks, except that the preliminary weighing of the timber shall be made after the steam treatment has been completed.

431. **Plant Inspection May be Waived.** Should the creosoting company be notified in writing that plant inspection will be waived on dimension timber, no field determination of quantity or quality of creosote will be made, but the creosoting company will be required to furnish a certified statement, signed by proper officers of the company, which statement shall indicate the amount of creosote oil injected and remaining in the timber, and the results of analysis of the oil, which analysis shall be made in accordance with the methods heretofore described in these specifications.

## FAILURE TO GIVE NOTICE OF TREATMENT.

432. Should the creosoting company fail to notify the State Engineer, Springfield, Illinois, of the date the material is to be treated as heretofore provided, then field determinations of quantity of creosote contained in the timber may be made in such manner as the engineer may desire, and if in his opinion the timber contains less creosote oil than required by the specifications, it shall be rejected.

## Asphalt and Asphalt Filler

### GENERAL.

433. The asphalt used for bituminous wearing surface, expansion joints, or for block or other filler, shall conform to the following requirements:

434. The various properties herein described are to be determined by the methods proposed by the American Society for Testing Materials.

### QUALITY.

435. **Specific Gravity.** The asphalt shall have a specific gravity not less than 0.97.

436. **Total Bitumen.** The asphalt shall be soluble in cold carbon disulphide to the extent of at least 98 per cent.

437. **Naphtha Insoluble Bitumen.** Of the total bitumen, not less than twenty-two (22) per cent nor more than thirty (30) per cent shall be insoluble in 86 degrees B naphtha.

438. **Loss of Evaporation.** When 20 grams (in a tin dish  $2\frac{1}{2}$  inches in diameter with vertical sides) are maintained at a temperature of 163 degrees C for 5 hours in a N. Y. testing laboratory oven, the evaporation loss shall not exceed 2 per cent and the penetration shall not have been decreased more than 25 per cent.

439. **Fixed Carbon.** The fixed carbon shall not exceed 14 per cent by weight.

440. **Penetration.** The penetration as determined with the Dow machine using a No. 2 needle, 100 gm. weight, 5 seconds time, and a temperature of 25 degrees C, shall not be less than 3.0 mm, nor more than 5.0 mm.

441. **Paraffine.** The asphalt shall not contain to exceed 2 per cent by weight of paraffine scale.

## Coal Tar Pitch Filler

### GENERAL.

442. Coal tar pitch when used for expansion joints or for block or other filler shall conform to the following requirements:

### QUALITY.

443. **Source.** Pitch filler must be obtained from coal tar only and there shall be no admixture of any material not obtained from coal tar.

444. **Specific Gravity.** The pitch shall have a specific gravity, at 25 degrees C, of not less than 1.22 nor more than 1.35.

445. **Free Carbon.** It shall contain not less than 22 per cent nor more than 30 per cent of free carbon, free carbon being defined as the organic material insoluble in cold carbon disulphide.

446. **Distillate.** On heating 100 grams of the pitch to 315 degrees C, the distillate shall not exceed 5 per cent by weight. The apparatus and its use to be the same as described in sections 409 and 410.

447. **Melting Point.** The melting point shall be not less than 60 degrees C nor more than 70 degrees C. The melting point shall be determined in the manner described on pages 20 and 21 of Bulletin No. 38 of the U. S. Office of Public Roads.

448. **Penetration.** The penetration as determined with the Dow machine using a No. 2 needle 50 gm weight, 5 seconds time, and a temperature of 25 degrees C shall be not less than 3.0 mm nor more than 5.0 mm quantity as will completely fill all joints between blocks. After the filler has been applied, the entire surface shall be covered with a light coating of clean, coarse sand or granite chips of a size that will pass through a  $\frac{1}{4}$  inch screen.

# SPECIFICATIONS FOR PILING

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449. **Quality.** Bearing piles shall consist of sound straight timber of a variety which will stand driving without splitting or undue brooming.

450. **Dimensions.** Piles shall have a diameter of not less than eight (8) inches at the small end or ten (10) inches at the butt. The bark shall be removed before driving.

451. The piles provided shall have sufficient length so that when all damaged wood has been cut off, the tops shall project about nine (9) inches above the bottom of the footing. The tops of piles shall not extend above the elevation of low water in the stream unless the piles are creosoted.

452. **Loading.** When used, piles shall be considered as carrying the entire load. They shall be spaced not closer than 2.5 feet center to center.

453. Each pile shall be considered as having a safe supporting capacity found by the following formula:

$$C = \frac{2wh}{S+1}$$

In this formula, C=safe load in pounds. W=weight of hammer in pounds; h=the fall of the hammer in feet, and S=the penetration in inches under the last blow assumed to be sensible and at an approximately uniform rate. S must be measured only when there is no visible rebound of the hammer, and the blow must be struck on practically sound wood. If the head of the pile becomes broomed in driving, the top shall be cut off to sound wood before taking the measurement for S.

454. The maximum load carried by any pile shall not exceed fifteen (15) tons.

# SPECIFICATIONS FOR STONE MASONRY

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455. **Quality of Stone.** The stone shall be clean, hard and of a kind known to be durable.

456. **Dressing.** The top and bottom beds shall be approximately parallel to each other and to the natural quarry beds, and shall be dressed to a surface which will admit of laying with joints not to exceed  $\frac{3}{4}$  inch. Vertical joints to be full for not less than 4 inches from the face. Corner stones shall have a chisel draft not less than  $1\frac{1}{2}$  inches wide. Faces shall be pitched to true lines.

457. **Size of Stones.** The individual stones, except for filling joints, shall have a thickness of not less than 8 inches and a width of not less than 15 inches. No stone shall have, however, a width of less than the thickness.

458. No stone shall have a length of less than  $2\frac{1}{2}$  feet or less than  $1\frac{1}{2}$  times its width except for headers. The length of headers may be limited by the thickness of the wall.

459. **Laying.** All stones shall be thoroughly drenched and laid in full mortar beds and all vertical joints shall be completely filled with mortar or spalls completely imbedded in mortar. One header shall be used to each three stretchers. Joints shall be broken at least 9 inches. Backing shall be carried up level with the face stones and shall be laid with full mortar beds and joints, with joints broken at least 6 inches.

460. **Mortar.** The mortar shall be composed of 1 part of Portland cement to  $2\frac{1}{2}$  parts of sand, the cement and sand to be of the quality specified for concrete.

461. **Coping.** Coping stones shall extend the full width of the wall with a 6 inch projection at the face.

462. **Pointing.** All joints shall be raked out to a depth of  $1\frac{1}{2}$  inches and bead pointed with a 1 to 2 mortar.

# SPECIFICATIONS FOR APPROACH GRADES AND WEARING SURFACE

463. Approach grades, back fill and wearing surface, unless particularly indicated under the heading of "Special Provisions" accompanying the proposal, shall not be included in the contract.

464. **Allowance for Settlement.** The approach grades shall have a top width as shown on the plans, or as indicated under "Special Provisions", side slopes of 2 horizontal to 1 vertical, and to allow for settlement, shall be carried to an elevation, above that indicated, an amount computed at the rate of one foot for each ten feet of depth of new fill.

465. **Materials and Compacting.** Approach grades and back fill shall be made in continuous horizontal layers not more than twelve inches in thickness, each layer being thoroughly hand or water tamped, before the next layer is placed.

466. No brush, rubbish or other material which by decay or otherwise might cause undue settlement will be allowed to remain in the fill. If required by the county superintendent, sheet piling, bracing forms and rubbish shall be removed from the excavation, before the back fill is made.

467. **Order of Placing.** Back fill on both sides of all walls shall be kept practically at the same elevation, as the fill is brought up. The back fill in all cases shall be carried up to the natural surface of the ground, as the same existed before any excavation was made by the contractor.

468. **Spandrel Fill.** The spandrel fill of arch bridges shall be composed of earth or gravel and shall be placed in layers of variable thickness simultaneously over all piers, abutments and arch rings.

469. At all points the ratio of the thickness of each layer to the total depth of the proposed fill shall be practically constant. The maximum thickness of any layer shall not exceed eighteen inches.

470. **Wearing Surface.** The wearing surface shall be composed of gravel, broken stone or other material as called for on the plans, or as indicated under "Special Provisions." It shall have the width and thickness shown on the plans, and shall be extended each way from the bridge to the end of the new approach fills.

471. Around all drain holes in the floor shall be placed a layer of coarse gravel or broken stone, not less than 6 inches in thickness, two feet in diameter, and centered over the drain.





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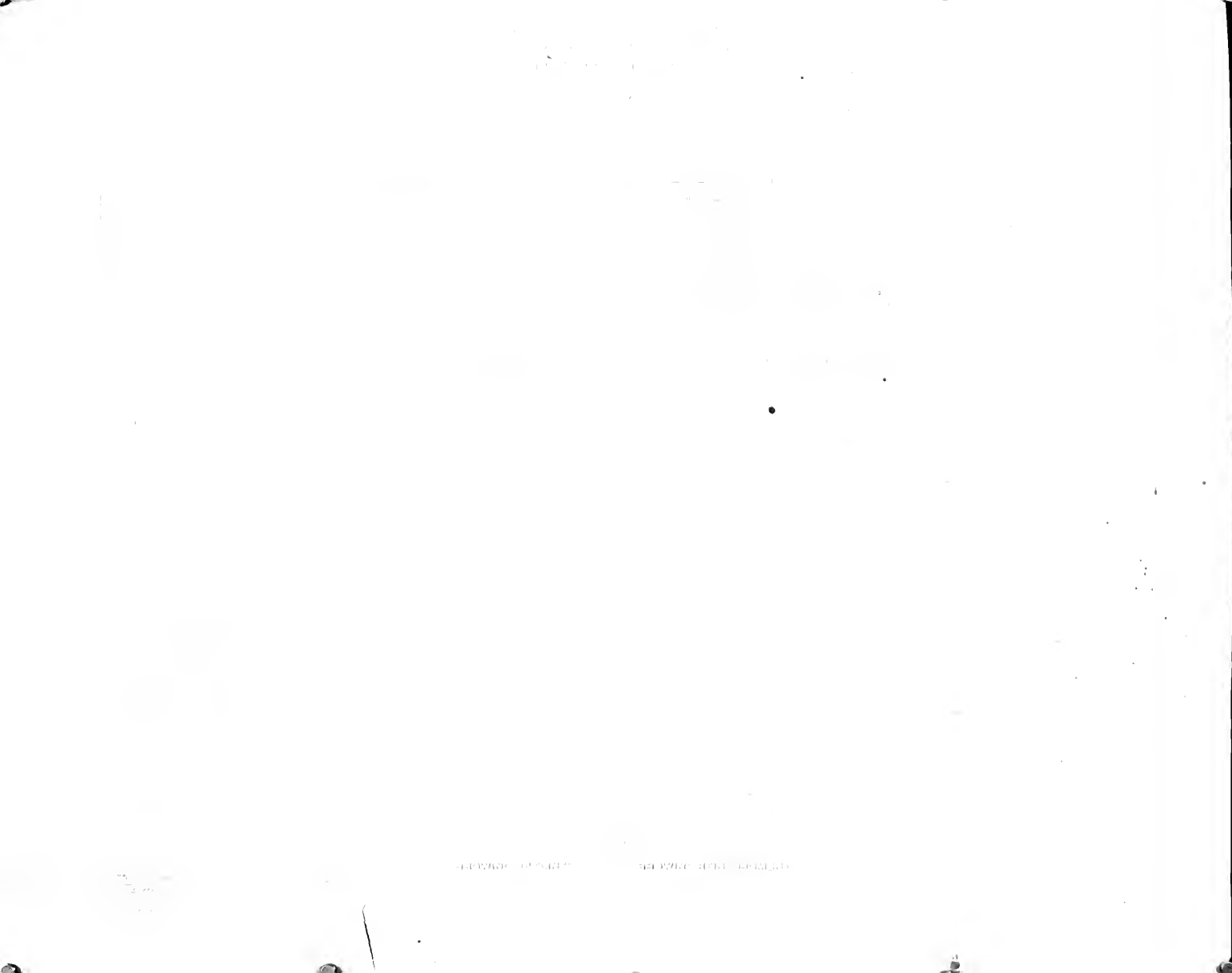
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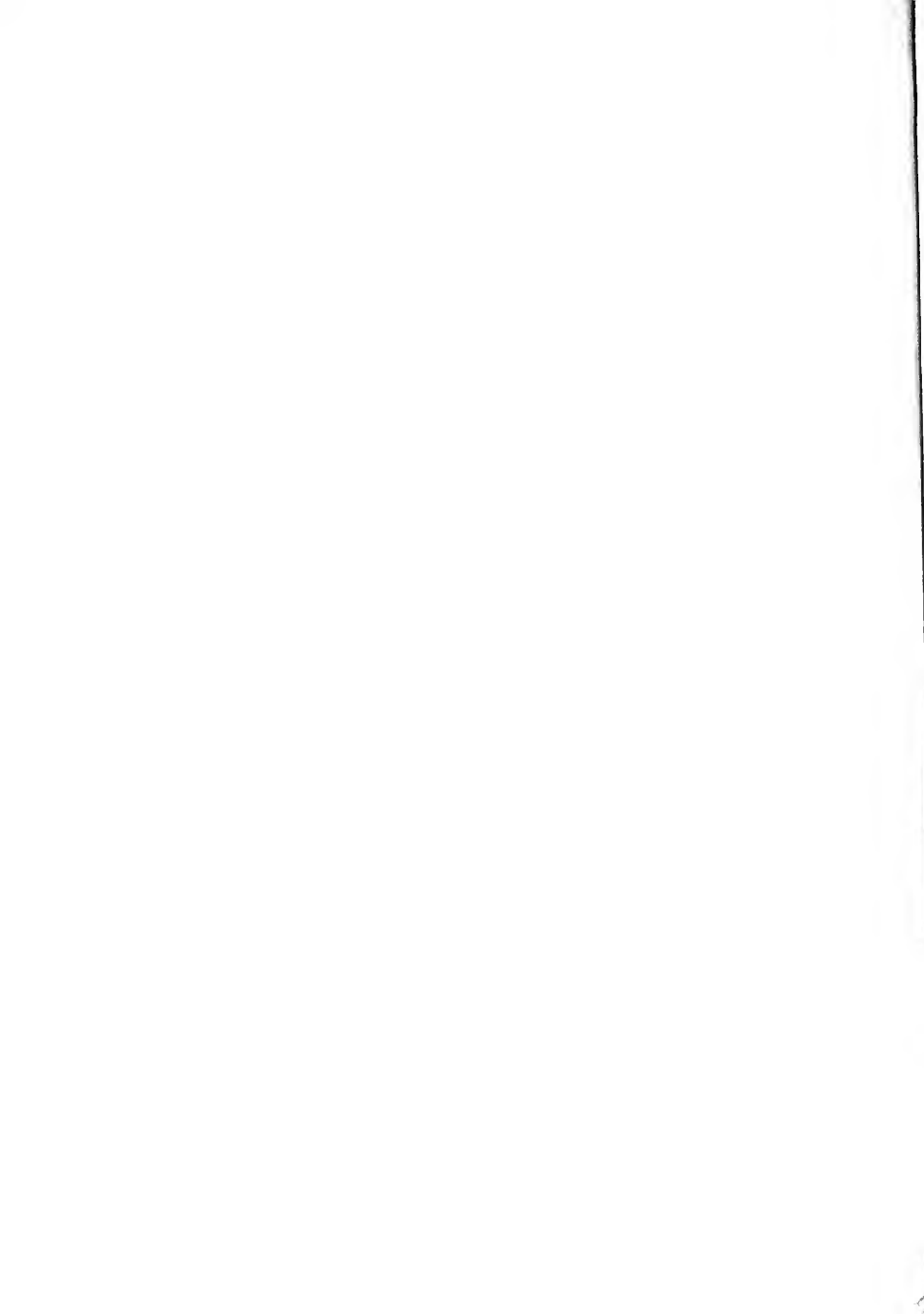


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